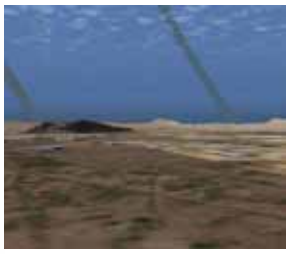
Building on the Legacy

A Year of Change, New Challenges, Performance and Result

Fiscal Year 2004 Report

Federal Aviation Administration

Human Factors Research & Engineering Division

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A Message From the Program Director

To Our Sponsors, Stakeholders, Partners and Research Team

Last year, we wrote of noteworthy success in all human factors program areas. I am pleased to report that 2004 results were even better. The human factors research team continued to build a solid foundation that will enable us to deliver sustained, strong performance into the future and help us remain at the top of human factors research organizations. Instrumental to this success was our alignment with the Air Traffic Organization (ATO) Operations Planning Services Unit (ATO-P) as part of the Research and Development Directorate (ATO-P R&D). Within this newly formed organization, we report to the Director, Office of Aviation Research and Development.

As mentioned above and discussed later in this report, the ATO stand-up emerged as a key activity in 2004. The ATO provides air traffic services that are highly valued by our customers. It is also implementing advanced cost and performance tools and techniques, and provides a focus on employee performance and accountability. Management layers have been reduced, communication between employees and management has been improved, and clear, specific goals and metrics have been established. To help baseline a starting point, the FAA directed an Activity Value Analysis to understand what we do at headquarters to support our people who deliver services directly to customers in the field.

The Activity Value Analysis helped us understand how research is resourced, what we produce, the value of products and services, how they meet sponsor and stakeholder needs, and how we compare to other FAA organizations. During this process, the Office of Management & Budget used its Program Assessment/ Rating Tool application to examine the overall R,E&D program. The result was the second highest score given to an agency program on its initial review.

The successes we enjoyed in 2004 came from the contributions of the talented men and women on the human factors research team. We see many opportunities to build on what we have achieved, strengthen our research portfolio, and continue our leadership in human factors research. I encourage you to read about our achievements in the pages that follow.

Paul Krois
Program Director (Acting)
Human Factors Research and Engineering Division

Recent Accomplishments

Developed future en route workstation concepts based upon application of human factors principles to ATC job requirements

Completed a cognitive work analysis of TRACON controller weather information needs

Developed software for an “e-JANUS” application; established on a web server

Completed a longitudinal assessment of Air Traffic Controller age and performance

Completed Aircraft Certification Job Aid Part 25 flight deck advance search function

Completed night vision imaging system lighting compatibility assessment methodology

Developed electronic flight bag usability assessment tools

Expanded the Threat and Error Management Model

Continued development of a Web-Based Surveillance and Auditing Tool (WebSAT) to analyze aircraft maintenance operations

Developed a human factors intervention matrix (HFIX) to complement the HFACS framework

Established a cabin safety research Center of Excellence

Initiated research focused on evacuation into water from very large aircraft (Airbus A-380)

Developed enhance cocaine analysis techniques

2004 – A Year of Change, New Challenges, Performance and Results

Change – The ATO

In February 2004, the FAA's Air Traffic Organization (ATO) became a reality and the Human Factors Research and Engineering Division, along with other legacy research offices, was aligned with the Operations Planning Service Unit (ATO-P). The ATO combined the Research and Acquisitions, Air Traffic Services, and Free Flight offices into one performance-based organization. This innovative achievement was necessary for the FAA to keep pace with industry and to operate effectively with reduced revenues. With this restructuring, the ATO became responsible for the direct, daily management of the Nation's air traffic control system. This new structure provides alignment and focus of resources at point of delivery and subsequently improves speed, flexibility, response and efficiency. The ATO faces many new challenges, and will need great cooperative efforts in three major areas to maintain its momentum in coming years: (1) to improve safety, even with growing congestion at major hub airports;(2) to reduce costs, even as our workload increases; and, (3) to optimize services to our customers, even as they struggle through a period of dynamic aviation industry change. ATO-P Human Factors Research and Engineering Division strategic activities directly support the Administrator's Flight Plan performance targets: Increased Safety; Greater Capacity; International Leadership; and, Organizational Excellence. Our role in the ATO provides an exceptional opportunity to meet Flight Plan Goals by operating more efficiently and effectively with new partners, new alliances, and new challenges. As we face these new challenges that are directed by the ATO and focused by the Flight Plan, we will continue to optimize our performance and produce world-class results.

New Challenges

The ideas of a talented program management and research team fuel innovation and power our approach to human factors research and engineering. With enduring budget constraints however, we frequently re-examined priorities to ensure we were on track and our focus was clear. If a need arose, resources were re-channeled to increase efficiency. This flexibility allowed researchers at the Civil Aerospace Medical Institute to quickly respond to a short-notice Congressionally-directed inquiry into the pilot Age 60 rule. In a similar vein, the human factors team at NASA-Ames partnered with researchers at the Volpe National Transportation Systems Center to conduct a "pop-up" assessment of a proposed traffic symbol set. We were also able to seek collaboration with the US Air Force Research Laboratory on a night vision imaging system lighting assessment methodology. Our approach to human factors research was, and is designed to identify and solve problems, manage costs, and deliver products to our customers. We do this by empowering people and collaborating with partners to meet challenges head-on, explore solutions, and then let them perform as we know they will.

Powering Performance

The ATO-P human factors research team believes "it is rocket science!" Becoming the research community's top-performing organization requires the ability to produce sustainable, long-term results. Our drive to produce is reflected in the number of products delivered to sponsors and to the field in 2004. It is also reflected in our commitment to deliver results the right way – by fueling innovation, empowering people, and building strong alliances and partnerships. Top results abound. Researchers at the William J. Hughes Technical Center delivered two key research reports and empirical controller performance data on the Future En Route Workstation. One report assesses a conflict probe on the Radar-side. The other report addresses additional human factors issues of optimizing the workstation. Aerospace Medical Team researchers established a new "Center of Excellence (COE)" to examine cabin air quality and study chemical and biological threats in airliners. Officially titled the "Air Transportation Center of Excellence for Airliner Cabin Environment Research," the consortium will research cabin air quality and conduct an assessment of chemical and biological threats. These products and information about them are connected to the aviation community by our fast-evolving human factors workbench. In addition, expanding web technology with its global network is enabling online real-time collaboration across the world's time zones.

Producing Results

The year 2004 will be remembered for successes that are already improving the safety and performance of air carrier crews, general aviation pilots, aviation maintenance and inspection personnel, air traffic controllers, and NAS system maintenance specialists. New products from the University of Central Florida and the University of Texas are expanding human factors considerations in aircrew training systems. The Volpe National Transportation Systems Center is enhancing the application of human factors in design and certification of new aircraft equipment as well as upgrades and modifications. In air traffic control, researchers at the William J. Hughes Technical Center and the Civil Aerospace Medical Institute are developing new products to improve decision support systems as well as innovative approaches to classify the human factors associated with operational errors. Research Integrations, Inc., a very-small business, is developing a computerized decision-support tool designed to help aircraft certification personnel ensure aircraft flight deck technologies are user friendly. The Aerospace Medical Research program is working hard to improve the safety, security, health, and survivability of civilian aircraft passengers and aircrews. In addition to the cabin air research mentioned earlier, researchers are evaluating the toxicological and medical findings from aircraft accidents and incidents to improve the safe operation of aircraft. They are also developing safety enhancing materials and structures, and evaluating survival equipment and procedures for aircraft occupant safety. The project reports that follow provide details of FY2004 results in all program areas. For more information, go to http://www.hf.faa.gov

Producing Results – Air Transportation Human Factors Research

Air transportation human factors research and products are enhancing the safety of the National Airspace System through improved crew training and safety data collection and analysis. Progarm Manager Dr. Eleana Edens directs research that provides methods and guidance for effective pilot training as well as valid and reliable assessment of flight crews and their training. The research also provides methods for airlines to collect and analyze different sources of operational safety-related information.

To be successful and provide valuable products to industry and the FAA, this research must consider distinct segments of aviation systems. Individuals comprising the crew, instructors who train and evaluate crews in the classroom, simulator, and airplane, line operations personnel, and the management culture responsible for air carrier safety are all areas of high interest. Researchers are studying the variables important to Line-Oriented Flight Training (LOFT) and Line-Oriented Evaluation (LOE) development, implementation and evaluation. This research focuses on: (a) LOFT/LOE development strategies; (b) instructor training; (c) LOFT/LOE development strategies; and (d) organizational and systematic influences on pilot performance, including the use of flight deck automation. In conducting this research, many sources of data are considered. Included is data from airline simulator sessions, airline flight deck observations, and traditional laboratory studies. The research examines methods to enhance the reliable and valid collection of operational safety data by providing taxonomies that incorporate human factors components of every-day airline incidents. This allows airlines to accumulate data that can be systematically analyzed to determine safety threats.

Air Transportation
Human Factors

Analysis of Pilot Procedures and Practices for Automated Flight Decks

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Automation introduced changes to the forms of crew interaction in the cockpit. Although designers hoped these changes would reduce errors, evidence suggests otherwise. This leads to the question of how we might improve the performance of crews using automated cockpit systems. One approach is to design cockpit procedures with automated systems in mind. Previous research has shown that development of specific standard operating procedures (SOP) can be successful in improving crew resource management performance. Developing procedures for automation interaction, however, requires precise knowledge of how pilot and crew processes contribute to automation problems. This project is concerned with understanding the dynamics of crew-automation interactions to improve systems and systems safety.

Methodology: This research assesses current problems with automated systems on the flight deck and develops potential solutions. In the first years of this program, George Mason University researchers developed a computational cognitive model that interacted with a simulated system for a single pilot. That work was leveraged to build a model of two crew members interacting in a highly automated and proceduralized cockpit. That work is now being coordinated with a regional airline partner. The team has examined errors occurring in the regional environment, and is using output from modeling efforts to develop new procedures for training and evaluation of crew-automation interactions. In addition, new projects are focusing on instrumentation for assessing flight performance as well as new instrumentation for implementing autoflight. Finally, subjective impressions are being collected via a survey (see image) regarding the safety of monitored approaches in support of proposed rule-making.

Results: Incident reports from the regional carrier suggest that a major problem is altitude deviations. Analyses of their programs suggest that problems can be tied, in part, to the automated systems that control their aircraft. These data are being used as the basis for development of new procedures to be trained and evaluated in the next year. In the area of new instrumentation, researchers found that functional displays (those that display functional relationships directly) can improve pilot performance even for experienced pilots. In work evaluating the design of a proposed new autoflight system, the analyses suggest that the proposed system should provide performance advantages. These predictions will be examined in 2005. In support of this work, researchers developed new analysis techniques for evaluating systems and pilot knowledge that are critical to understanding how to improve system design.

Recent Accomplishment: New systems analysis and knowledge elicitation techniques provide a firm foundation for the development of new designs. Collaboration between industry, academia, and the FAA allow the output of these analyses to improve safety in the operational environment. Partnerships also highlight the importance of collecting and evaluating data on an ongoing basis in the operational environment.

Primary Investigator: Deborah A. Boehm-Davis, George Mason University, Fairfax, VA

Advancing Aviation Safety: Threats, Errors and their Management in Normal Operations

FAA Sponsor Organization: Flight Standards Service, Air Transport Division

Purpose and Rationale: Researchers at the University of Texas are investigating relationships between operational complexity, flight crew error, and flight crew performance in normal flight operations. Knowledge gained will help support proactive safety efforts by identification of incident and accident precursors *before* they become consequential. The Threat and Error Management (TEM) model is the data framework underlying development and refinement of two proactive data collection programs: the *Line Operations Safety Audit* (LOSA) and the *Aviation Safety Action Program* (ASAP). It is envisioned that a common framework will emerge to allow personnel from different areas of an airline (safety, training, flight operations, dispatch, etc.) to identify and address common problems.

Methodology: This project uses two methodologies to examine threat and error management performance in normal operations: non-jeopardy, confidential cockpit observations (LOSA) and crew incident reports (ASAP). LOSA captures data from the observer's perspective; ASAP captures data from the crew's perspective. These complementary approaches provide a more complete picture of system safety. Work on ASAP has expanded from collaboration with a single airline to three airlines, leading to the ASAP Data Sharing Project, a demonstration with the goal of supporting de-identified sharing of ASAP data. Participating airlines use software developed by the researchers, and will make their data available in a de-identified format.

Results: In 2004, the LOSA Archive was developed. Data has been collected from 20 LOSAs over the past eight years. Data from the first six developmental LOSAs have been retained but excluded from the archive. The archive contains more than 3,000 jump seat observations, 11,000 threats, and 7,000 errors. The qualitative data (phase-of-flight narratives) supplement the quantitative data (threat and error type, crew action, outcome). Results of analyses will be reported in safety digests, at industry meetings, and posted on-line. For ASAP, work focused on expanding the project from creating an ASAP program at one airline, to creating a project that enables participating airlines to use the software and share the data in de-identified form with researchers and other airlines.

Recent Accomplishments: Establishing the LOSA Archive will enable industry-wide analyses and trending of safety vulnerabilities and strengths. The LOSA methodology was promoted at a two-day event in Dublin, Ireland attended by representatives from 40 airlines, 12 civil aviation authorities and aircraft manufacturers. The ASAP Data Sharing Project has developed a shorter, web-based ASAP reporting form, and developed the ASAP Manager Application that facilitates collecting and tracking reports and corrective actions.

Primary Investigator: Robert L. Helmreich, The University of Texas, Austin, TX

Interruptions, Distractions, and Lapses of Attention in the Cockpit

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Inadvertently failing to perform an intended action (e.g., set flaps to take-off position) is one of the most common of cockpit errors, one that has contributed to many accidents. This NASA-Ames study identified the primary causes of inadvertent errors of omission as interruptions, distractions, and the demands of managing multiple tasks concurrently. By characterizing the cognitive demands of typical flight situations requiring pilots to manage concurrent tasks, researchers prepared a foundation for designing operating procedures and training to reduce vulnerability to this common form of error.

Methodology: Jump seat observations were used as an ethnographic approach to characterize the pattern of occurrence of interruptions and distractions and concurrent task demands in typical cockpit operations and to identify how crews respond, and what types of error occur. The team collected jump seat data, observed training, and analyzed operating procedures at two major U.S. airlines, analyzed a large number of ASRS reports, and analyzed all 19 U.S. airline accidents between 1990 and 2000 in which the National Transportation Safety Board identified crew error as among the probable causes.

Results: Researchers completed collecting and analyzing data and have largely completed a first draft of the report which will be published in book form. Results reveal that interruptions and distractions are frequent, that conditions often force crews to defer tasks out of the sequence called for in operating manuals, and that often multiple tasks must be managed concurrently rather than serially. In these situations, human cognitive processes are quite vulnerable to error and typical airline training provides little guidance on how to manage these situations. In the full report, which will be finalized this winter, concrete suggestions are provided for ways training and operating procedures can be improved to reduce vulnerability to error. (See image, next page)

Recent Accomplishment: In collaboration with Captain Robert Sumwalt, Chair of the ALPA Human Factors and Training Committee, and Captain Ron Thomas, Manager of Training at U.S. Airways, NASA provided detailed input to the FAA for expanding AC 120-71A, *Standard Operating Procedures*, and AC 120-51E, *Crew Resource Management,* to provide guidance for crew monitoring as a major defense against errors and threats. This input was incorporated into the revised advisory circulars. In addition, a major U.S. airline drew heavily upon the research in a complete overhaul of all normal flight operating procedures.

Primary Investigator: Key Dismukes, NASA-Ames Research Center, Moffett Field, CA

Aviation Safety Reporting System (ASAP) Classification System

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: The American Institutes for Research is developing a taxonomy for classifying human factors issues identified as primary or contributing causes in Aviation Safety Action Program (ASAP) incident reports. Although several coding systems already exist, detailed information concerning their development and psychometric properties remains largely unavailable. Moreover, none of the existing systems permit the user to integrate ASAP data with data from other voluntary safety programs in the search for trends. The research team is using a combination of data-driven and theory-driven methods to create a flexible, inclusive taxonomy of human factors issues. This taxonomy will be embedded in a web-based data collection and reporting tool that provides query and data analysis capabilities, allowing air carriers to develop interventions and empirically assess the effectiveness of these interventions.

Methodology: Review of existing human factors taxonomies, accident/incident reporting systems, and data collection tools yielded a list of approximately 300 commonly used aviation human factors issues. With this information, research tasks focused on developing and testing the taxonomy. First, a series of card-sorting exercises were conducted with subject matter experts (SME) to identify how they cognitively organize these human factors issues into categories. The data were analyzed via hierarchical cluster analysis and SME review. Once the categories were established, pilots were invited to take an online survey to verify that the human factors issues could be reliably assigned to one of the seven categories. Senior level SMEs reconciled the human factors issues that were not reliably assigned. Finally, ASAP meeting attendees read actual de-identified ASAP reports, and then assigned a primary and a second causal factor to the incident using the taxonomy.

Results: The card-sorting exercises identified a seven-category solution for organizing human factors issues. The online survey revealed that some human factors issues could not be reliably assigned into a category. Although three senior SMEs reconciled the assignments, these inconsistencies prompted viewing the empirical assignment of the issues by category with a more rational eye towards usability. Finally, results of the causal factor assignments using ASAP reports revealed how pilots would use a taxonomy, thus identifying the strengths and weaknesses in the taxonomy. For example, pilots had difficulty separating process issues from outcome issues. The variation in level of specificity in issues in the same category was confusing. Some category definitions were incomplete. Modifications made to the taxonomy as a result of these discoveries were relatively minor, but were significant in terms of usability and reliability.

Recent Accomplishment: The research team developed a human factors taxonomy and made progress on transitioning this taxonomy into an online reporting system that is currently being developed. Once the reporting system is complete, pilot test data will be collected on taxonomy assignments for three months. Results of analysis will be used to make final modifications to the taxonomy and the system.

Primary Investigator: David P. Baker, American Institutes for Research, Washington, DC

Training/Assessing Aircrew Skills to Achieve Reliable/Valid Performance Data

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Researchers at the University of New Mexico are developing and validating methods to improve pilot training and evaluation. Research is focused on investigating methods Instructor/Evaluators (IE's) use to assess pilot performance and IE ability to reliably grade pilot performance. Research includes: (a) developing Instructor/ Evaluator Training & Calibration (IETC) software to generate graphical statistical reports of IE grading performance; (b) revision of the Internal Evaluation Programs Advisory Circular (AC 120-59); (c) investigating whether specific changes in critical flight parameters affected IEs' grading of technical maneuvers using animated landings; (d) developing a PC-based flight simulation for research on learning and transfer of piloting skills; (e) investigating the effect of expectancy on performance of critical skills; and (f) conducting a survey of air carriers on their use of ASAP.

Methodology: Researchers developed and administered questionnaires to understand how air carriers use IEP and ASAP programs and to determine their perceived needs. The team used experimental methods to systematically investigate the role of expectancy on performance during rejected takeoffs and developed measures of pilot performance on rejected takeoffs from flight parameter data (e.g., reaction time to pull back throttle and distance from center line). They also developed software to perform latent semantic analysis (LSA) on ASAP narratives. LSA is a method for extracting semantic information from a large corpus of text. Several carriers are interested in applying LSA to help automatically categorize and interpret ASAP narratives.

Results: IE's continued to grade pilot performance on landings as above average when approach speed was manipulated to well above levels specified in qualification standards. Also, students' ability to perform a rejected take-off was impaired as expectancy of occurrence of the event was lowered. A major air carrier collaborated to create a new version of the IETC software that displays IE performance graphically. The team successfully modified existing flight simulation software to allow manipulation of a host of flight variables to create and store flight parameter data files that reflect pilot performance. They also facilitated revision of the IEP advisory circular (AC 120-59) by coordinating efforts from US air carriers.

Recent Accomplishment: Modification of flight simulation software will have important implications for future examination of learning, retention, and transfer of pilot skills. Off-the-shelf simulation software allows a user to engage in many important perceptual-motor tasks involved in flying. However, it is poorly suited for research because it does not allow manipulation of specific flight variables or storage of performance data for statistical analysis. These problems were solved by developing special code to interface with existing flight simulation software. For example, researchers investigated expectancy effects on rejected take-off (RTO) performance. They presented subjects with a predetermined sequence of normal take-offs (NTOs) within the context of a high frequency of RTOs. Task conditions were changed to emphasize NTOs, and after performing several NTOs, students unexpectedly received an RTO. The software allowed the creation of sequences of trials with different characteristics and the recording of flight parameter data for assessing performance. This software now allows examination of important factors related to training, retention, and transfer of critical skills.

Primary Investigators: Timothy. E**.** Goldsmith, Peder J. Johnson, University of New Mexico, Albuquerque, NM

Improving the Training of Automated Flight Deck Skills

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: This research seeks to find if there are accurate and cost-effective alternative evaluation methods to measure a pilot's knowledge of automation as well as the skills required to fly today's modern automated aircraft. Options such as card sorting and concept mapping are examples of concepts being considered to replace traditional methods such as written exams and oral evaluations.

Methodology: The Team Performance Laboratory at the University of Central Florida (UCF) created a new software tool, Team Performance Lab Knowledge Assessment Tool Set (TPL-KATS), for assessing complex knowledge structures and mental models necessary for the operation of advanced transport category aircraft. Researchers are using this tool to evaluate pilot automation training. The goal of the project is to develop a system that will allow evaluators to diagnose problem areas within knowledge structures based on the mental models being represented.

Results: In cooperation with several airlines, researchers are examining the capabilities of the TPL-KATS to evaluate pilots' knowledge of automation. These investigations yielded results that show the concept mapping and card sorting techniques are comparable to traditional testing methods.

Recent Accomplishment: In 2004, UCF researchers used the TPL-KATS tool to collect longitudinal data from pilots as they are going through initial training in an automated aircraft at a major air carrier and at a regional airline. These data are currently being analyzed.

Primary Investigator: Florian Jentsch, University of Central Florida, Orlando, FL

Notices to Airmen Survey Research

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Notices to Airmen (NOTAMs) are temporary notices that contain important time-critical information that pilots need in order to make informed decisions when planning flights. These notices provide information such as airport closures, airspace restrictions, and closed runways. This NOTAM project analyzed the human factors aspects of the NOTAM system to determine how pilots can obtain the most useful information from the system, and assesses whether changes might lead to substantial performance improvements.

Methodology: Researchers at the University of Central Florida (UCF) distributed a survey to 79 pilots who revealed that it is easy to make mistakes using the NOTAM system, and that NOTAMs can be easily misinterpreted. Furthermore, pilots suggested that ways to improve the system include the use of plain language, creating a single source from which all NOTAMs can be obtained, and better organization of the NOTAMs.

Results: This project resulted in a technical report highlighting the issues of concern with the current NOTAM system and providing suggestions for possible improvements to the system, locally, nationally, and internationally.

Recent Accomplishment: In 2004, UCF researchers briefed the results to the Air Transport Association NOTAM Task Force, the International Civil Aviation Organization (ICAO), the Director of Flight Standards at the FAA (AFS-1), and the NOTAM Summit organized by the Office of the FAA Administrator.

Primary Investigator: Florian Jentsch, University of Central Florida, Orlando, FL

Pilot Training for Unexpected Events

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Current research seeks to identify underlying skills needed by pilots to respond to unexpected events. The focus is on investigating alternatives and modifications to traditional training, targeting these skills, and developing ways to augment the pilots' ability to respond to an unexpected event and any resultant consequences of that event.

Methodology: Researchers at the FAA and the University of Central Florida (UCF) are investigating factors that influence a pilots' reaction to unexpected events. They developed a theoretical framework, identifying key concepts related to the occurrence of and training for unexpected events.

Results: Recommendations regarding development of training interventions to manage unexpected events, such as scenario-based training, meta-cognitive training, and adaptive expertise training have been presented to the FAA.

Recent Accomplishment: In 2004, UCF researchers completed four studies on unexpected events. In the first study, a survey was constructed to ascertain pilots' perceptions of unexpected events and learn what types of events pilots find surprising or unexpected and how they might affect the outcome of a flight. Analysis of survey data is expected to give insight into how pilots view surprise and unexpectedness, and what other types of outcomes are generated from these events. The data will also show the type and extent of training pilots receive on dealing with unexpected events.

The purpose of the second study was to explore and analyze the effects of preparatory information (priming) delivered through preflight planning information (e.g. aircraft maintenance status logs) on pilots' reactions to unexpected events. This study indicated preparatory information (contextual cuing) which is contrary to what might be expected, had an effect of lowering the perceived probability of that event occurring during the experimental flight, thus eliciting more surprise.

In the third study, a database review was undertaken to determine: (a) the extent to which pilots encountered surprise and unexpectedness in flight operations resulting in unwanted outcomes; (b) what types of occurrences pilots perceived as surprising or unexpected; and (c) if any common themes emerged. Results of this study indicated five distinct factors involving surprise and unexpectedness resulting in an event, incident, or accident: aircraft state, other's actions or instructions, environment, other aircraft, and NOTAMs. Common threads included: (a) surprise can be insidious; (b) surprise can be subliminal; (c) what is unexpected and surprising to us is typically something common, trivial, and mundane; finally, (d) there were cues available to suggest that the unexpected should have been expected.

The fourth study determined which factors play a part in creating an unwanted outcome due to a surprising or unexpected event. Research suggested that a persons' reaction to a surprising or unexpected event may contribute to an interruption of ongoing cognitive and motor activities. The extent to which this potential interruption of ongoing activities occurs in the task of flying may influence the outcome of a maneuver or even the entire flight. Data were extracted from over 800 reports. Eighty-two variables were recorded for analysis by researchers holding pilot and flight instructor certificates. Inter-rater reliability was greater than 97%. Results of the analyses that are currently underway are expected to add to our understanding of the variables involved in unwanted outcomes due to the effects of surprise.

Primary Investigator: Florian Jentsch, University of Central Florida, Orlando, FL

Scenario Generation with the RRLOE/RRLOS Tool

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: The Team Performance Laboratory at the University of Central Florida developed the Rapidly Reconfigurable Line Operational Simulation/Evaluation (RRLOS/RRLOE) computerized scenario generation system for the FAA's Voluntary Safety Program Office. RRLOS allows training developers to combine training event sets and create training materials. It also generates scenario scripts in real time.

Methodology: Researchers are developing and testing software that will accurately, efficiently, and quickly evaluate pilot performance and training needs using a realistic set of events.

Results: Using the software, a two-hour training scenario can be generated in five to twenty-five minutes versus two to six weeks previously. The software can target specific skill areas, thereby allowing the quick generation of scenarios that are customized to the trainee and his/her training needs, and include customized training materials such as scenario scripts and supporting materials.

Recent Accomplishment: The tool has been delivered to over 50 air carriers and other aviation organizations. In 2004, UCF researchers updated RRLOE/RRLOS, increasing its functionality, and continued to provide training to airline staff and crew. In total, UCF researchers have trained over 60 individuals in the use of the tool.

Primary Investigator: Clint Bowers, University of Central Florida, Orlando, FL

Integrating Human Factors/Usability into Operating Documents

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: In support of industry efforts to achieve technical data standards, this project provides an industry forum to help operators transition from document systems to re-usable information systems that facilitate data exchange across organizations. This includes the transfer of flight operational information from manufacturers and regulators, to operators, and within companies to user communities such as flight operations, technical publications, technical operations, and safety/quality assurance. Although commercial software solutions have been developed to permit the efficient use of common data structures and re-usability of data, the transformation from current legacy systems to common information warehouses serving diverse users is a major challenge. This project distills a complex set of technical issues into a focused subset of airline requirements for the exchange and revision of operational data. Specifically, a prototype Common Data Structure usable to both the airlines and the manufacturers has been developed and evaluated by members of the industry group.

Methodology: Participants include major air carriers, regional carriers, cargo operators, manufacturers, and the FAA. Over the years, the focus has shifted from development of document systems to digital data and issues related to data exchange. During 2004, a subgroup called the Operational Testing Group (OTG) supporting the ATA Flight Operations Working Group (FOWG) helped develop a usable data interchange format (Common Data Structure), and the framework, guidance and tools for testing its ability to meet typical operator revision requirements. The product of this work was the Electronic Revision Prototype (ERP), a CD tutorial and demonstration of operational data from different suppliers (manufacturers and vendors) in a standard, open source format that could be imported into data/document management applications. The ERP was introduced to the larger NASA/FAA Operating Documents group at Workshop VI, held in Orlando, FL November 2003. (Note: see image, next page).

Results: The 64 participants of the NASA/FAA Operating Documents Workshop VI met to discuss the development of a Common Data Structure for the exchange of data between suppliers and operators during the revision process. In addition to presentations by operators and demonstrations of vendor products, an interactive explanation of the ERP was provided by the OTG. The ERP gave a step-by-step overview of the new data structure with details of the information units that would allow more efficient revisions and better reuse. Each Workshop participant was given a copy of the ERP on a CD-ROM in order to assess a preliminary version of the Common Data Structure. Their feedback on how the Common Data Structure could affect their current revision processes was later analyzed and reported to the ATA FOWG and the ATA Future Data Exchange group. A follow-up Metadata Workshop held in July continued dialog on high priority data standard needs, specifically the MMEL industry group (IG).

Recent Accomplishments: For 2004, the primary accomplishment was the development and demonstration of the Electronic Revision Prototype by the OTG subgroup of the NASA/FAA Operating Documents Group. The ERP was introduced to, and evaluation data was collected from participants of Workshop VI. On the basis of this evaluation, a report was written and submitted to the ATA FOWG as well as the Future Data Exchange (FDE) group. In addition, the results of the Metadata Workshop held in July, provided industry feedback regarding MMEL metadata and the use of XML schemas to the MMEL industry group (IG) and a survey to the MMEL-IG for continued data collection.

Primary Investigators: Barbara G. Kanki, NASA-Ames Research Center, Moffett Field, CA; Thomas L. Seamster, Cognitive & Human Factors, Santa Fe, NM

Radio Communications Simulation (RCS) Project

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Communication simulation plays a crucial role in testing and training of pilots. However, if the simulation is not appropriately realistic and fails to test or train for critical behaviors, its usefulness is significantly undermined not only for an absence of testing/ training, but for testing or training inappropriate behaviors. Unrealistic testing and training can also promote a false sense of security that eventually betrays the users' confidence when conditions do not perform in reality as they do in simulation. Prior simulation studies (laboratory and field settings) at NASA aptly demonstrated the need for integrating some level of realistic, yet cost-effective communication simulation into pilot training. This year's effort was to evaluate the technical guidelines for integrating realistic radio communications into flight simulation. The evaluation addresses: speech recognition reliability requirements, voice numbers and types, intelligibility and naturalness of text-to-speech engines, content of ownship and frequency chatter, instructor interface requirements, simulator integration, and database maintenance requirements.

Methodology: Because significant advances in computer, visual display, motion and force cueing and other technologies have had a dramatic effect on the design and use of simulation in aviation and other fields, it is important to re-visit the issue of realistic communication in flight simulation in a comprehensive way. Many aspects of testing and training can be improved, but the decision on how to increase realism is a matter of balancing multiple and diverse costs and benefits. The cost-effective use of new technologies in training, safety investigation, engineering and scientific research requires a broad-based understanding of capabilities and limitations. As the technology has as its primary goal the creation of virtual environments for human users, knowledge of human sensory, perceptual, and cognitive functioning is also needed. The final report (in the form of a book publication) integrates the specific findings of the previous simulation studies and raises them to higher level principles for designing appropriate ATC communication systems.

Results: The results of the three previous studies demonstrate limitations of the current level of realism of communications in flight simulator testing and training of pilots. For example, study one showed that realistic communications reduced the amount of time pilots spent in planning and decision-making as time spent communicating with ATC increased. Study two validated the increased pilot-ATC time and showed some tendency for call-sign confusion to emerge. Study three showed that background frequency chatter increased workload for both flying and non-flying pilots. The integrated report will focus on three main areas: (1) simulation technology and the human response (including topics such as auditory displays and communication simulation); (2) simulation technology applied (including relevance to training and evaluation as well as engineering and system safety); and, (3) simulation technologies - problems and promises (including technology limitations and issues pertaining to simulation fidelity and transfer of training.)

Recent Accomplishments: A culmination of the simulation studies was presented at the meetings of the Royal Aeronautical Society. A comprehensive review of the issues pertaining to communication system technologies will be covered in a book, *Flight Simulation: Virtual Environments in Aviation*, to be published later this year.

Primary Investigators: Barbara G. Kanki, NASA-Ames Research Center, Moffett Field, CA; Alfred T. Lee, Beta Research, Inc., Los Gatos, CA

Simulator Fidelity Requirements

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: to ensure that flight-simulator qualification standards, which are becoming regulatory, are necessary and sufficient for effective yet affordable pilot training and evaluation equipment. A review of flight-simulator qualification standards identified two issues: (1) there is a lack of evidence that existing qualification standards for flight-simulator platform motion are optimum for producing transfer between simulator and airplane. Because of this, there is a need for research to establish scientifically sound recommendations on possible future refinements with regard to such standards; (2) distractions stemming from radio communications between aircrew and outside the cockpit may not be accurately represented in the simulator, resulting in a less challenging training and evaluation environment in the simulator than the one encountered during actual flight.

Methodology: (1) Platform motion. Two earlier studies that had been published separately using different types of statistical analyses were consolidated. Two quasi-transfer studies (where the simulator with motion represented the airplane in the final transfer test) had been performed within the recurrent training and evaluation context. The first study used a typical and the second study an enhanced motion-system configuration, yielding different results. To legitimately compare the two studies, multivariate analyses were applied to both studies. A second effort was to plan an extension of the investigation of the motion requirement to the context of initial pilot training. The main task was to find an airline partner. A third effort comprised a review of the current airplane-simulator qualification documents, which will further support the FAA's efforts to refine and consolidate the existing standards in a new Part 60 of the Federal Aviation Regulations. A fourth effort was directed at developing a systematic approach to re-examine past studies addressing the question of simulator motion. Finally, Volpe continued to maintain a vast electronic library that is being used by researchers internationally. (2) Radio communications in the simulator. Efforts in 2004 comprised an update on current radio-communication simulation practices, industry initiatives and literature. This involved interviews and site visits with airlines and industry and participation in the Royal Aeronautical Society's Simulation of the Environment Conference.

Results: The consolidation of the two studies on the effect of motion on recurrent pilot training and evaluation showed that effects were found only with enhanced motion, underscoring the importance of motion-cue quality. However, these results did not necessarily point to an advantage of motion. A small reaction time advantage of the pilots flying with motion disappeared once all pilots transferred to motion. Generally, pilots flying without motion adopted steadier control-input strategies, and sometimes flew more precisely, even when motion was resumed. Regarding the effect of motion in initial training, materials describing the rationale and method of the planned study were developed to submit to airline partners. Several candidates were visited to discuss the requirements of the study. Simulator availability, technical support, and cost are the main issues in the discussions. For the simulator qualification review, relevant findings based on the literature survey were summarized and directions for future research to improve the guidelines were suggested. Finally, a systematic approach to aid the interpretation of past and the design of future studies based on experimental validity and reliability and pilot-vehicle closed-loop control theory criteria was developed. The electronic literature data base was expanded to almost 600 titles. The update on radio communications found that despite technological advances and a

consensus that a realistically simulated environment is very important for effective pilot training and accurate evaluation, the fiscally ailing airlines may need further incentives to assume the costs involved.

Recent Accomplishments: Both the motion simulation and the radio communication simulation requirements research continue to generate much interest from industry and regulators. This is documented by the invitations to present the work to groups such as the International Air Traffic Association (IATA) Flight Simulator Working Group and the Royal Aeronautical Society, and by being repeatedly sought out by organizations facing decisions addressed by our research. The work also contributes to increased research activities in the area, especially regarding the effort to improve qualification standards. All this helps to find a sound scientific basis for decisions that, in the past, have often been predominantly based on subject matter expert opinion. We were able to generate interest from several airlines and training centers in the planned study on the effect of platform motion on initial pilot training. These collaboration efforts are currently being negotiated.

Primary Investigator: Judith Bürki-Cohen, Volpe National Transportation Systems Center, Cambridge, MA

Mixed-Fleet Flying of Automated Aircraft and Flight Deck Automation Issues

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: The research results under this study are intended to assist certification and design personnel in identifying and assessing design-induced human performance errors that contribute to aviation incidents and accidents. The results will assist in identifying potential mismatches between operator capabilities and limitations, and avionics design characteristics that should be addressed in the certification process. The focus of this year's work was to investigate safety issues associated with mixed-fleet flying of automated aircraft and update the flight deck automation issues database and website (www.FlightDeckAutomation.com).

Methodology: Research Integrations, Inc. developed a mixed-fleet flying safety vulnerability analysis to identify potential safety issues with mixing two automated airplane types. A full list of pilot tasks was used to direct the assessment of the information and actions required to accomplish each task in each of the two airplanes. The resulting list of vulnerabilities was to be verified as part of a longitudinal study. The mixed-fleet flying longitudinal study began on January 5, 2004 at Delta Airlines with an initial evaluation data collection. Subsequent data collection evaluations were conducted at 90-days and 180-days following the initial data collection. The data collection for the 180-day evaluation will continue into the next year.

The research team also maintained and updated a flight deck automation issues database and website that provides a comprehensive list of automation human factors issues as well as research data and other objective evidence related to those issues. Accidents, incidents, and research studies related to automation issues were reviewed to update information in the database.

Results: The mixed-fleet flying longitudinal study has completed the initial data collection phase and the 90-day evaluation phase. The data collection phase at 180 days after the initial session is in progress. Videotapes of the data sessions will be analyzed to assess the criticality of the safety vulnerabilities identified in the analysis.

Recent Accomplishment: The Flight Deck Automation Issues Website is now being used by many industry representatives for research and program development purposes. From October 2003 through August 2004, there have been 6,080 unique visits to the website, an average of 552 unique visits per month.

Primary Investigator: Elizabeth Lyall, Research Integrations, Inc., Tempe, AZ

Enhancing Pilot Training Using the Model AQP Database

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Research conducted by the University of New Mexico and American Institutes for Research shows that pilot crew resource management (CRM) performance ratings correlate more highly by event set than by CRM skill. These findings demonstrate the critical impact situational variables (e.g., phase of flight and conditions) have on crew performance. The current research has two objectives: To identify the implications of situational factors for training CRM, and to create a methodology for designing event-based training that supports identification of key combinations of maneuvers and conditions that provide important opportunities to acquire and maintain flight management proficiency.

Methodology: Three activities support the goals of this research:

- *Identify Situational Factors* by analyzing each phase of flight and maneuver to identify the key factors that must be effectively managed
- *Develop a Metacognitive Model of Crew Functioning* that supports the integration of situational and human performance factors within a common framework
- Create an Event Catalog, with each event supporting links to both the situational factors identified in Activity 1 and the metacognitive model developed in Activity 2

Results: Although this project is not yet complete, we have made significant progress in developing a methodology that we believe provides a useful strategy for bringing together the physical variables of the operational environment and the flight management strategies utilized by the crew within a coherent analytical framework. We have created diagrams for each of the key maneuvers that indicate the dominant variables (aerodynamic, weather, etc.) that affect the performance of those maneuvers together with the key aircraft systems used to manage their impact. These diagrams offer meaningful representations of maneuver structures from which higher-order, operationally meaningful concepts can be created. In addition, we have developed a metacognitive representation of the crew that reflects the interactive, dynamic nature of crew performance. This representational scheme, the circuit, includes four major parts (planning, performing, assessing, and modifying), each of which is supported by a set of strategies that can be used to more effectively perform that part. The higher-order concepts created to represent the clusters of interrelated physical variables are brought together with the metacognitive crew representation through the event methodology designed to support the event catalog.

Primary Investigator: Susan Mangold, Battelle Memorial Institute, Columbus, OH

Producing Results – Aviation Maintenance Research

Aviation Maintenance human factors research has the overall goal to identify and optimize the factors that affect human performance in maintenance and inspection. The focus initiates on the technician but extends to the entire engineering and technical organizational and all personnel involved in the endeavor. Research attention to personnel can include selection, qualification, training, motivation, health, professionalism, and the variety of human capabilities and limitations that affect efficient and safe maintenance task performance. The research considers many aspects of the work environment including both the physical and social aspects of the organization. The complexity of technical communication is an example of such research. The diversity of maintenance and inspection activity is unlimited. Thus the research attends to each and every action preformed by individuals, teams, departments, and the collective organization. With a view of people, the environment in which they work, and the actions they perform a final focus is on the resources necessary for efficient and safe work. Research related to resources includes studies on the design of documentation and procedures, selection of tools, equipment, buildings, applications of advanced technologies for maintenance and inspection. The maintenance human factors research combines critical basic scientific understanding of human performance with applied studies conducted in cooperation with industry partners. The results are solid and proven science, psychology, and engineering delivered in plans, procedures, software, and even hardware that can be immediately implemented to affect efficiency and safety. To obtain a detailed description of current aviation maintenance human factors projects, projects completed, accomplishments, and products delivered, please point to **http://www.hf.faa.gov/maintenance.htm**. Dr. Bill Johnson is the Chief Scientist of Aviation Maintenance Human Factors and Dr. William "Kip" Krebs is the research program manager.

Aviation
Maintenance

Use of Advanced Technology to Support Inspection Training in the General Aviation Industry

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: A sound aircraft inspection and maintenance system is vital in providing the public with a continuing safe, reliable air transportation system. This is true for both general as well as commercial aviation. Since it is difficult to eliminate errors altogether, continuing emphasis must be placed on developing interventions to make the inspection/ maintenance system more reliable and/or more error tolerant. Training is a primary intervention strategy to improve the quality and reliability of aircraft inspection and reduce errors. In response to this need, the research team used multimedia-based computer training and low fidelity simulation techniques to develop a computer based training system for general aviation entitled " General Aviation Inspection Training System: GAITS". It is anticipated that the use of this tool will alleviate problems inherent with On the Job Training (OJT), resulting in standardization of the inspection training process. This will yield improved inspection performance resulting in reduced errors.

Methodology: The research will utilize an integrated task analytic and iterative software development methodology. The motivation is to improve inspection performance via development of training programs based upon task analyses of the existing environment. The first step uses task analysis to identify factors affecting aircraft inspection performance and, subsequently, using those factors to develop a framework to understand inspection performance. Based upon this framework, intervention strategies will be identified that reduce their drawbacks. Later, the investigative team will identify which of these can be most impacted by training. Following this step, a training program will be developed using the classic iterative development methodology.

Results: With the results from the task analysis and error taxonomy, performance objectives of the training program were developed and evaluated by industry partners. Detailed functional and technical specifications for the training program were developed. Following this, the team identified content, methods and delivery systems for training, and developed alternate methods for training. Repeated meetings were conducted with the subject matter experts and feedback forthcoming from these meetings was used in updating and organizing the training content, methods and delivery systems. The research team then integrated the training material and methods. Detailed storyboards for organizing material for inspection training were developed. Once the training content and method were developed and organized, and feedback sought from subject matter experts, alternate interface prototypes were developed. These were evaluated by primary, secondary, and tertiary users; feedback was sought to develop the final interface for the GAITS software. The GAITS software is organized into four separate modules [Introduction, Training, Design & Analysis, and Simulator]. Multimedia data [text information, images of structures/defects, videos and voiceover support] for specific inspection activities were developed and organized. The research findings were then disseminated including through scholastic publications.

Recent Accomplishments: Developed and organized material for inspection training. Developed interface prototypes of GAITS. Feedback for GAITS was collected to design the final interface. Research findings were disseminated through scholastic publications.

Primary Investigator: Anand K. Gramopadhye, Clemson University, Clemson, SC

An Examination of Maintenance-Related GA Accidents in the United States

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Commercial air carriers have invested a great deal of resources to address human factors issues in maintenance, while GA and corporate aviation have lagged far behind in establishing a similar safety culture. With as much as 96% of active aviation in the United States comprised of either GA or corporate aviation, this lack of attention is surprising. In fact, studies have found both GA and corporate aviation lacking in any sort of structured safety management systems for maintenance operations, in spite of the fact that maintenance related accidents comprised as much of 21.3% of accidents in 1997. This contrasts with a reported 9.7% maintenance related accidents from 1987 to 1996 reported by Boeing in 1997. In light of the fact that the accident rate for GA aircraft is five to seven times that of commercial air carriers, these percentages take on more significance. This investigation has two purposes. One is to test the human error underlying maintenance operations associated with GA aircraft. The second purpose is to compare the errors made in Alaska (AK) with the continental United States (US).

Method: The National Transportation Safety Board's (NTSB) Accident and Incident Data System was utilized to identify maintenance related causal factors. Two methods were used to select the maintenance factor sample. First, a sample of causal factors was selected from the years 1990-2000 based on: (1) NTSB personnel codes that identified the involvement of maintenance personnel; and (2) NTSB subject codes that identified maintenance factors. Either criterion qualified a factor to be part of the maintenance factor sample. The second method of sample selection used causal factors identified by subject matter experts (SMEs). The combination of these two methods resulted in 2227 maintenance related causal factors for 1935 accidents. These causal factors were classified into Human Factors Analysis and Classification System (HFACS) categories independently by six certified, instructor level airframe and power plant mechanics who are serving as mechanic SMEs.

Results: The HFACS analyses revealed no differences between AK and the US. Taken as a whole, the data revealed that the most common human errors in GA maintenance were skill-based errors (43.3%). Violations (V) by AMTs were the second most common factor associated with maintenance-related accidents at 23.7%, followed by owner-operator violations (VOO) (11.3%). Finally, decision errors (DEs) represented the least common factor associated with maintenance-related accidents (8.9%). A fine-grained analysis of the unsafe acts indicated that the most common skill-based errors were installation errors followed by inspection errors. The most common violation for AMTs were also associated with installation, however, for owner-operators, the most common violation was failure to obtain an annual inspection. Finally, the most common DE noted in the sample was non-compliance with airmen's directives. In relating maintenance unsafe acts to fatalities, those accidents that were associated with VOOs were over twice as likely to result in a fatality.

Recent Accomplishments: Over one third of the unsafe acts were violations committed by either the AMTs or the owner-operators of the aircrafts. It was also determined that the risk of fatality increases over two-fold when VOOs are associated with maintenance related accidents.

Primary Investigators: Albert Boquet and Cristy Detwiler, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Effects of Fatigue/Vigilance/Environment on Inspectors Performing Fluorescent Penetrant and/or Magnetic Particle Inspection

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Recent accidents have emphasized the importance of inspection reliability to aviation safety. One key aspect of reliability is the effect of long, continuous working times of inspectors. Extended time periods could cause a vigilance decrement and/or fatigue in inspectors, leading to reduced defect detection performance. This may be particularly apparent under conditions of highly repetitive tasks and darkened conditions, typical of fluorescent penetrant and magnetic particle inspection tasks. Researchers at State University of New York – Buffalo are seeking evidence as to whether this phenomenon exists for fluorescent penetrant inspection (FPI) or magnetic particle inspection (MPI).

Methodology: This research uses a two-phased approach. Phase I sets up the conditions and materials for formal experimentation while Phase II uses a two-step methodology to run the experiments. Phase I began with a review of the relevant literature. A number of site visits were used to address environmental and temporal conditions of inspection, and collect survey data on hours of work. In Phase I, the experimental materials consisting of high-quality photographs of engine blades were assembled. Phase I also produced a report on temporal effects on inspection. In Phase II, a six-factor screening experiment is used to measure probabilities of hit and false alarm, plus time taken per item. The two hour task is performed in day and night times, with or without breaks, in light and dark conditions and with different types and probabilities of defects. Mental workload of inspectors and sleepiness are measured. Any significant factors or interactions will be explored further in a series of parametric experiments. The final report will be supplemented by a Best Practices Guide.

Results: The first report on this project summarized the effects of temporal factors on inspection performance. A computer program for simulating FPI inspection has been written and tested. The program has a full complement of 63 engine blades, a comprehensive data collection facility and a good navigational interface. An interactive training program has been written as a MS PowerPoint presentation. Both the training program and the simulation were tested on six engineering students to find any problems with the programs, and to establish data needs by measuring the rate of inspection chosen by the participants. An operational test and validation of the simulation program and the training program was performed at a partner airline where six NDI technicians experienced in FPI were given training and the opportunity to test the simulation. Researchers received a number of suggestions for changes in both training and simulation. Overall, the inspectors stated that they would believe recommendations for fatigue control based on use of this simulation. The mean rate of inspecting blades was 41 per hour, not significantly different from the student pilot subjects ($t(5) = 0.14$, $p = 0.90$). As a result, several changes were made to the simulation and training programs. The experiment for data collection is underway using local factory workers trained for the simulation task.

Recent Accomplishment: A paper on the temporal aspects of inspection was presented at the Human Factors and Ergonomics Society 2004 annual meeting.

Primary Investigator: Colin G. Drury, University at Buffalo: SUNY, Amherst, NY

Do Language Barriers Result in Maintenance Deficiencies?

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Outsourcing is a preferred corporate strategy for reducing nonessential costs and focusing an organization on its core business. In aviation maintenance, outsourcing has been advocated and widely used, as it avoids tying up capital in maintenance facilities, and can reduce costs by opening the airline's maintenance operation to outside competition. One potential impact of such outsourcing is that there are more interfaces within the system, each of which represents an opportunity for error. The existence of maintenance and inspection personnel whose native language is not English suggests that language barriers may be causing performance errors. This project at State University of New York – Buffalo examines whether such errors exist, what patterns characterize these errors, what their contributing factors are and how effectively we can mitigate these errors.

Methodology: Language errors can be characterized as communication errors by definition. The first step in this research was a review of models of communication to search for characteristic error patterns. Researchers identified two primary communication types relevant to aviation maintenance: synchronous communications (largely verbal and informal) and asynchronous communication (largely written and formal). They analyzed several error databases (e.g. ASRS) and found that both the contributing factors and the use of recovery mechanisms were different for the two error types. Next, survey data from 113 aircraft operators was analyzed, covering their English speaking/reading abilities and use of mitigation strategies.

Results: The research team collected intervention effectiveness data on 254 participants in mainland China, Hong Kong, and Taiwan during two separate trips to Asia in 2004. This data is being used to quantify the effectiveness of representative intervention strategies to reduce language-related errors. In addition, 249 completed questionnaires were obtained, which are being used to better quantify the incidence of each type of language error identified in the taxonomy from Phase I. During the visits to 11 sites, the researchers conducted 12 focus groups, which provided valuable information on how these Maintenance, Repair and Overhaul (MRO) facilities currently mitigate potential maintenance deficiencies caused by language barriers at work place. The MROs provided samples of their typical work cards and job aids (e.g., bilingual aircraft maintenance glossary) for reference. To date, the incidence data show that the main factors affecting language error incidence are task complexity, instruction complexity, inadequate English ability (written and verbal) and time pressure ($F(8,96) = 29.1$, $p<0.001$). Analysis of the intervention evaluation showed that intervention affected time more than accuracy, the three countries visited gave different results, and that years as an aviation maintenance technician was a significant covariate. The only intervention significantly better than the others was full translation into Chinese.

Recent Accomplishment: The full data base from Asia on the scenario incidence, contributing factors , and intervention evaluation is proving most comprehensive.

Primary Investigator: Colin G. Drury, University at Buffalo: SUNY, Amherst, NY

Vision Testing Requirements for Certain Persons Maintaining and Inspecting Aircraft and Aircraft Components

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Although good vision is a vital qualification for aircraft maintenance inspectors, no general standards for visual acuity currently exist for this occupation. Vision standards from other occupations cannot be "borrowed" to set a standard for maintenance inspectors because the visual demands between occupations are dissimilar and the majority of occupational vision standards are not empirically based. In this project, we apply a novel methodology toward defining an empirically based visual acuity standard for a representative task performed by aircraft maintenance inspectors.

Methodology: Computational models of visual discrimination have been validated against tasks such as letter discrimination, military tank detection in complex environments, and detection of simulated aircraft on runways. Last year, NASA researchers improved one of these models by recalibrating it to some newly acquired population data. They have since run the model on 52 cracks of different lengths and widths at five levels of blur. So that the image characteristics are exactly known, visual acuity declines are simulated by blurring the image rather than with blurring lenses. To obtain predictions for the detection of airframe cracks, this year the model was expanded to include the possible masking effects of the airframe surround. Predictions of two versions of the model were compared, one which assumes a homogeneous background with a stimulus just in a narrow area of the entire image, and another model which takes the whole image, with background airframe parts, into account. NASA is currently validating the model with data collected in both naive people and highly trained maintenance inspectors. Because of the quantity of the data required to fully validate the model, the non-experienced observers are collecting data on 52 crack images at five levels of blur and two distances with three repetitions on each condition while the NDI/NDT inspectors are validating a subset of the conditions.

Results: Both the model and psychophysical data show that the airframe structures surrounding the crack can affect the crack's visibility. Similarly both the quantitative model and psychophysical data show that increased blur raises crack detection thresholds.

Recent Accomplishment: In spite of the complex political climate within aircraft maintenance workplaces, NASA researchers have identified the planned number of inspectors for model validation from within airlines and in the military.

Primary Investigators: Bettina L. Beard and Albert J. Ahumada, Jr., NASA Ames Research Center, Moffett Field, CA

*D*evelopment of a Web-Based Surveillance and Auditing Tool (WebSAT) to Analyze Aircraft Maintenance Operations – Phase I: Identification of Process Measures

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Evaluation of the aircraft maintenance system requires an analysis of maintenance processes in use. Such an analysis will provide management with feedback on the performance of the airline, and consequently provide proactive support to the decision-making process prior to the dispatch of the aircraft. As surveillance, auditing and airworthiness directives form a significant portion of the quality assurance function of an airline, it is critical that data be collected on these functions. This research focuses on development of a proactive system (WebSAT), which promotes standardization in data collection and identifies factors that impact aircraft safety.

Methodology: To achieve standardization in data collection, data needs to be obtained on certain variables which measure maintenance processes and eliminate existing inconsistencies. These variables are defined by the research team as process measures. The process measures incorporate the response and observation-based data collected during surveillance, audits, and the control of airworthiness directives. This research employed data collection methodologies such as observation sessions, interviews, and surveys for identification of process measures. Data captured in terms of these process measures facilitates data analysis and subsequently identifies the potential problematic areas affecting the safety of an aircraft.

Recent Accomplishment: The WebSAT team has identified adequate process measures to incorporate relevant data obtained from surveillance, auditing and airworthiness directives work functions. An online survey (below) has been launched to validate the identified process measures with the help of partnering airlines. The input from this survey will allow the research team to refine and iterate research findings on the identified process measures.

Primary Investigators: Anand K. Gramopadhye and Joel S. Greenstein, Clemson University, Clemson, SC

Impact of Vision Testing Requirements on Non-Destructive Inspection (NDI) / Non-Destructive Testing (NDT) and Visual Inspection Personnel

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: The National Transportation Safety Board cited the failure to identify visually detectable corrosion, cracks, or inclusions as the probable cause of several aviation accidents. Good vision is critical to the success of Non-Destructive Inspection and Testing (NDI/NDT) procedures and visual inspection tasks. NDI/NDT personnel must use their eyes, with or without various aids, to make judgments about the condition of aircraft and aircraft components. While there are recommended near and distance visual acuity standards for NDI/NDT personnel, similar guidelines do not exist for visual inspectors. Maintenance facilities often use the same testing requirements for visual and NDI/NDT inspectors. This project will determine acceptable vision standards and screening procedures for NDI/NDT and visual inspectors.

Methodology: Researchers observed inspectors at maintenance facilities as they performed visual inspection duties on various types of commercial aircraft. Measurements of visual tasks were taken and the type of equipment used was noted. Other data included the type and frequency of procedures performed and vision screening practices. Demographic statistics were collected to provide a profile of the NDI/NDT and visual inspector workforce. Vision screening was performed on current NDI/NDT and visual inspectors to identify ocular health and refractive status.

Results: Data collected from over 4000 observations revealed working distance distributions of aviation maintenance inspectors are dependent on specific inspection activity. For fluorescent penetrant inspection, 93% of fixations were at or near 50 cm. For borescope inspections, intermediate distance viewing (> 50 cm but d" 1 m) was most common. For visual inspections, working distance distributions were between these extremes; 72% near, 19% intermediate. Since inspectors must identify defects viewed at near and intermediate distances, revised vision standards may be warranted. A survey of 889 NDI/NDT workers revealed that 99% were male, with a median age of 45 years. Ethnic diversity included 73% Caucasians, 13% Asian-, 7% Hispanic-, 6% African-Americans, and 1% others. NDI/NDT personnel performed eddy-current inspections most often, while radiographic inspections were performed least. Preliminary analysis suggests that the visual capabilities and ophthalmic conditions related to males over 40 years of age should be considered in the application of vision-screening programs.

Recent Accomplishment: Researchers conducted facility and personnel surveys at several maintenance facilities and detailed visual-task analysis at five aircraft maintenance facilities. In addition, vision screening of 150 inspectors was performed at two aircraft maintenance facilities. Consolidation and analysis of the data collected during the study are ongoing.

Primary Investigators: Van B. Nakagawara, FAA Civil Aerospace Medical Institute, Oklahoma City, OK; Gregory W. Good, The Ohio State University, Columbus, OH

*D*evelopment of Guidelines and Tools for Effective Implementation of an Aviation Safety Action Program (ASAP) for Aircraft Maintenance Organizations

FAA Sponsor Organization: Flight Standards Service, Voluntary Safety Programs Branch

Purpose and Rationale: Aviation Safety Action Programs (ASAP) identify and correct adverse safety events that would otherwise not likely come to the attention of the FAA or company management. As of December 31, 2003, there were twenty-eight airlines that operated ASAPs for pilots, but there were only six ASAPs for aircraft maintenance mechanics. Of the six maintenance ASAPs, most are considered by all stake-holders to be highly effective. Because of the potential benefits to safety, a major interest of the FAA is to determine whether the failure of ASAPs to expand to multiple operators as rapidly for aircraft maintenance as it has for pilots is attributable to FAA's ASAP policy, or to other factors beyond the control of the FAA.

Methodology: The first year of this project consisted of two phases: coordination and survey development. The coordination phase was critical to the success of this project because it focused on informing the stake-holders (air carriers, FAA inspectors, and labor unions) about the purpose and scope of this research project. Focus-group discussions were used to develop a Maintenance ASAP Questionnaire (MAQ). Approximately 83,000 individuals were randomly selected from a population of about 130,000 aircraft mechanic certificate holders. Assuming that at least about 50% of the recipients are actively involved in aviation maintenance, about 40,000 individuals were likely to be realistic candidates for the survey. The typical response rate for mail-in surveys is 30% and the typical response rate for mail-in surveys from aircraft mechanics is about 10%. Therefore, it was likely that between 4,000 and 12,000 surveys would be returned. As of September 8, 2004, 5,022 responses have been received.

Results: Focus group discussions resulted in development of the MAQ - a 104-item survey questionnaire that was distributed to 83,000 aircraft mechanic certificate holders. The results of the focus group discussions were presented at the *Safety Across High-Consequence Industries Conference* in St. Louis, MO. A preliminary analysis of the survey data indicates that ASAP programs in maintenance organizations are influenced, at least in part, by the following factors: (a) awareness about the ASAP program - knowledge about acceptance criteria, reporter protection, benefits of the program, and workload involved in managing an ASAP program; (b) attitude toward current (typically internal) safety reporting systems - issues involving interpersonal trust, labor-management relations, and role of the respective labor unions; and (c) management's support and the overall culture of open communication - past handling of confidential information, corporate disciplinary policy, and the perception of one's ability to effect change through such programs.

Recent Accomplishment: This is the largest and most comprehensive survey of its kind. The response to this survey has been very positive. Responses were received from all 50 states and the District of Columbia.

Primary Investigator: Manoj S. Patankar, Saint Louis University, St. Louis, MO

Producing Results – Flight Technologies and Procedures Research

Flight technologies and procedures research addresses human factors considerations in the design, certification, and approval of new technologies, procedures, and capabilities that cut across several operational environments of major and regional airlines. Program Manager Dr. Tom McCloy directs research that includes:

- Development of a job aid for use by designers and certification personnel to identify and address human factors issues with flight deck technologies and systems during the certification process
- Development of human factors considerations in the design and evaluation of electronic flight bags
- Assessment of human factors issues and design characteristics of profile situation displays
- Assessment of human factors issues in the design and certification of multi-function displays and controls
- Assessment of human factors issues associated with depicting weather on flight deck displays

Flight Technologies
& Procedures

FAA Aircraft Certification Job Aid for Flight Deck Human Factors

FAA Sponsor Organization: Northwest Mountain Region Transport Airplane Directorate

Purpose and Rationale: Aircraft certification requires judgments about whether new aircraft designs will be safe to be flown in the global airspace by current and future pilots. Although experience has shown that design-induced human performance errors have contributed to many aviation incidents and accidents, there is a lack of guidance describing what human performance areas should be evaluated and, until now, there have been only a few methods available to help certification personnel predict the future occurrence of such errors based on analysis of the flight deck design. The FAA Aircraft Certification Job Aid is a computerized decision-support tool designed to help aircraft certification personnel ensure aircraft flight deck technologies are user friendly.

Methodology: This PC-based software has three major databases addressing regulatory information, flight deck components, and human factors considerations. The current version is focused on air transport category aircraft. During this year, researchers reviewed FAA regulatory information and other human factors literature for human factors systems-related information to update the databases.

Results: Researchers developed a hierarchy of 16 human factors considerations to address topics related to the design of flight deck systems. The hierarchy of human factors considerations was tested and it was confirmed that these included all the issues pertinent to the design and certification of flight deck systems. The information in all three databases was expanded to address systems-related human factors. Updates to the previously addressed display-related and control-related information in these databases were also made to include new and revised FAA regulatory information.

Recent Accomplishment: This year, a limited number of certification personnel continued to use the fielded version of the Job Aid in their jobs and are providing feedback for future version enhancements. An advanced search function has been developed to greatly enhance the speed with which the certification personnel can access the extensive human factors information found in this decision support tool. The search function allows for keyword searches of all Part 25 regulatory and guidance information as well as all summaries of human factors information addressing the design of flight deck displays, controls, and systems.

Primary Investigator: Elizabeth Lyall, Research Integrations, Inc., Tempe, AZ

Weather Displays

FAA Sponsor Organization: Aircraft Certification Service

Purpose and Rationale: Weather, traffic, and other flight information can play an integral role in supporting strategic and tactical flight. However, if basic human factors principles are not considered, the presence of all this information in the cockpit can compromise safe flight. Researchers at Kansas State University developed a usability assessment tool for use by FAA certification officials and avionics manufacturers prior to certification. The tool utilizes behaviorally based metrics for evaluating the degree to which a display conforms to FAA and human factors guidelines for presenting information in the cockpit. The goal for 2004 was to evaluate a certification assessment protocol (CAP) with two-person teams (designated as "supervisor" and "user"). The team addressed the ability of the "supervisor" to record "user" performance and the ability of the "user" and "supervisor" to identify bottlenecks, diagnose bottlenecks, and classify them as violations of FAA and human factors guidelines.

Methodology: Based on a usability assessment, a methodology for assessing cockpit displays during certification was proposed that requires at least two personnel, a "user" and a "supervisor" recording user performance. An evaluation of the CAP was conducted, focusing on its ability to satisfy time and personnel constraints. FY 2004 research addressed the ability of certification personnel serving as the "supervisor" to document "user" performance and the ability of the "user" and "supervisor" to identify bottlenecks, diagnose their causes, and classify those causes as violations of FAA and human factors guidelines. The team assessed how human factors and aviation-related experience affect the usability of the CAP. These issues were addressed by a mock certification session with GA pilots and human factors personnel assuming the roles of certification personnel.

Results: The mock evaluation results indicated that with minimal training and experience with the CAP, "supervisors" were able to sufficiently document "user" performance and identify bottlenecks. Steps are being taken to modify the CAP to better support accurate diagnosis and classification of identified bottlenecks. Based on favorable feedback from FAA and various ACO personnel, two additional components are being integrated into the CAP that assess the extent to which the MFD relies on memory and requires head-down time to perform tasks. The next phase is to conduct another mock certification session in order to evaluate the extent to which the additional components result in a more comprehensive evaluation of a complex MFD. For the next phase, actual certification personnel will serve as end-users of the CAP.

Recent Accomplishment: This project led to development of a more behavioral-based avionics certification process. Through implementation of benchmark tasks and a user-testing paradigm, certification personnel can systematically and efficiently evaluate avionics with regard to real-world tasks. Also, the approach provides a more behaviorally-based usability criterion on which to evaluate avionics displays. The 2004 evaluation of the CAP indicates that it has been successfully adapted to assess additional issues posed by more complex MFDs (e.g., information overlay, etc.). Thus far, feedback from avionics manufacturers and ACOs for this behaviorally-based approach has been favorable.

Primary Investigator: John Uhlarik, Kansas State University, Manhattan, KS

Profile Situation Awareness and Required Navigation Performance Information Displays

FAA Sponsor Organization: Aircraft Certification Service

Purpose and Rationale: Many avionics vendors are enhancing horizontal situation awareness displays and navigation displays by incorporating two new types of information: (1) profile information, displaying vertical information in a "sideways" view; and (2) Required Navigation Performance (RNP) information. This research will support development of human factors certification standards and guidelines. Research program products include: (1) a quick reference checklist of questions that certifiers can use when evaluating profile displays; (2) a bank of anticipated issues in profile displays for aircraft certification; (3) requirements expressed in RTCA minimum operational performance standards documents; and (4) a report on issues concerning map displays used in an RNP environment.

Methodology: Standards and guidelines were developed through an industry and literature review and participation on RTCA committees charged with drafting and publishing standards for profile and RNP map displays. The resulting standards and guidelines are documented in RTCA standards, a report titled *Issues and Design Tendencies in Profile Situation Awareness Displays*, and a technical memo, *Human Factors Design Issues of Electronic Map Displays Used in an RNP RNAV Environment*. The information for the quick reference checklist and the issues bank is derived from the report *Issues and Design Tendencies in Profile Situation Awareness Displays*. Each issue identified in that report is summarized as a quick reference item and used to generate a set of entries for the issues bank. Each entry is written as a ready-to-copy certification-issue report action item for profile displays.

Results: Profile displays are being pursued by no less than five avionics manufacturers. These displays are being developed to address a number of dimensions of situation awareness, most notably terrain, energy, and stability. Laboratory research also suggests that profile displays can improve RNAV mode awareness and understanding. However, proper design of the profile displays present a number of human factors trade-offs, and certifiers need to evaluate the rationale used by manufacturers in selecting display location, size, scale factor ratio ("aspect ratio"), ownship movement, orientation, and swath shape and behavior. RNP has relatively little impact on the human factors of map displays, and established map standards and guidelines are largely applicable and sufficient. However, certifiers should be especially aware of the difficulties of adequately designing such a map display to provide fine course guidance.

Recent Accomplishments: Completion of the certification bank of anticipated issues in profile displays.

Primary Investigator: Michael Zuschlag, Volpe National Transportation Systems Center, Cambridge, MA

Electronic Flight Bags

FAA Sponsor Organization: Aircraft Certification Service

Purpose and Rationale: Electronic flight bags (EFBs; see image, next page)) are being introduced into the flight deck, bringing with them many human factors challenges. Although EFBs may look like familiar equipment, they are new devices from a flight deck perspective because of their flexible configurations and functionality. The FAA put forth a streamlined field approval process for EFBs in Advisory Circular (AC) 120-76A. The AC addresses human factors considerations, but the procedure for doing an evaluation is not specified. AC120-76A refers to a comprehensive document for further information, but the depth and breadth of that document make it cumbersome to use in field inspections. This research is developing tools to aid FAA aircraft certifiers in conducting structured and comprehensive EFB usability evaluations in the field. It is expected that the tools will benefit the FAA, system designers, and operators by providing structure for human-factors evaluations.

Methodology: EFB usability assessment tools were refined over the course of several tests with systems that were volunteered by vendors. Test methods were adapted from standard techniques in usability engineering. Aviation/human factors experts worked in teams to evaluate EFBs through co-discovery with a think-aloud protocol. The evaluation consisted of task-based exploration and a tool-based review using two different paper assessment tools. One tool was a short high-level list of usability topics that evaluators should consider during a brief evaluation. To use this tool, evaluators go through the high-level tool commenting aloud about each item. The second was a lengthy detailed tool consisting of over 200 items. To use the detailed tool, evaluators go through one item at a time, deciding whether the system complies with that item or not.

Results: Results from evaluations yielded tools and procedures that show great promise. In the course of this research, two key lessons were learned. First, language used in the tools is especially important for evaluating EFB usability. Tools must be understood by a wide range of users, with and without a human factors background. Second, having an observer dedicated to keeping detailed notes about the evaluation enhanced the quality of the evaluation. Although the tools were designed for FAA users, they will also be used by manufacturers. Some manufacturers are considering how to fit them into existing design and development processes. Using the tools could be a relatively inexpensive way to catch significant problems early on and to track progress on addressing the problems.

Recent Accomplishments: The final EFB Version 2 document was approved for release by the FAA. It is posted on the Volpe EFB website. This document includes a review of industry EFB technology from September 2003, and is in widespread use by industry and the FAA. Researchers developed two usability assessment tools. The tools were refined based on iterative testing. Two rounds of tests were conducted with prototype commercial EFB systems. A report on research to design and test a tool for assessing the usability of EFBs was submitted to the FAA for review. The report is based on several iterative tests of the tool.

Primary Investigator: Divya Chandra, Volpe National Transportation Systems Center, Cambridge, MA

Flight Symbology

FAA Sponsor Organization: Aircraft Certification Service

Purpose and Rationale: A Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) for aeronautical symbols (SAE ARP 5289) was released almost a decade ago, but the recommended symbols are not in widespread use for various reasons. Some manufacturers have developed their own symbols, resulting in a variety that could be confusing and potentially misleading. Therefore, it is necessary to understand what display technologies are in use, what symbology is in use, and how symbols can be improved and made acceptable for broader use. The task is complex because of the wide range of display platforms and uses for navigation symbology. Results of the research are expected to be of use to industry and the aviation authorities responsible for establishing symbology standards.

Methodology: Commercially available systems used in general aviation (GA) were previously identified. In FY 2004, four manufacturers that produce air transport displays were contacted and asked to provide specifications for what they considered to be their low-end and high-end displays. Volpe researchers worked with the FAA to identify and prioritize issues with symbology proposed for depiction on electronic map displays. This was important in supporting the most urgent needs of FAA representatives to ICAO. These research issues were documented in a conference paper. Volpe also worked with the FAA to develop a suitable experiment design.
Volpe researchers participated in SAE G-10 Electronic Charting Committee and continue to insure that up-to-date information from other relevant committees is available to the FAA.

Results: From a symbology perspective, the biggest difference between low-end and high-end displays in GA is display resolution. For air transport displays, while display resolution is still important, it is not a limiting factor. Resolution of what was considered a low-end display for air transport aircraft was higher than the resolution for some high-end displays used in GA operations. The important issue for air transport displays is optimizing contrast.
There is currently no common standard across organizations and manufacturers regarding what symbols to show on electronic displays of navigation information. Experiments to address higher-level issues related to the design of effective symbology are being developed. The experiments will examine the usability of the US-proposed charting hierarchy, and end-user population stereotypes for different navigation symbols. Data collection will begin in fall, 2004.

Recent Accomplishments: A paper documenting research issues in the design of symbols for navigation displays was compiled and circulated among FAA and industry. This paper was presented at the 23rd Digital Avionics Systems Conference (DASC) in October, 2004. An experiment design has been finalized and is being implemented. The experiment will address issues such as the usability of the US-proposed charting hierarchy, and end-user population stereotypes for different navigation symbols. Data collection began in the fall, 2004.

Primary Investigator: Divya Chandra, Volpe National Transportation Systems Center, Cambridge, MA

Guidelines for Certification of Head-Up Displays

FAA Sponsor Organization: Aircraft Certification Service

Purpose and Rationale: Manufacturers are meeting an increased demand for head-up displays (HUDs) by marketing new models with various innovative features (Note: see image, next page). These HUDs present human factors issues regarding the accessibility of information displayed and the location of HUD elements so that critical information is sufficiently conspicuous but does not interfere with the out the window (OTW) view or with other nearby information. These two goals tend to be contradictory: a large, detailed, information-rich, and centrally located indicator design will also tend to clutter the OTW view and the display itself. However, a small, basic, information-impoverished and peripherally located indicator design may be difficult to use for its intended task. From a human factors perspective, the HUD design must achieve a balance between these goals. FAA Aircraft Certification needs guidelines for evaluating this balance as presented in a HUD design seeking certification.

Methodology: In FY 2004, researchers at Volpe conducted an experiment to evaluate the impact of gradation marks on altitude and airspeed indicators, markings which the FAA has identified as a design feature where guidelines are needed for HUDs. Additional work was conducted by experimentally comparing alternative tape formats for heading, altitude, and airspeed indicators to assess the performance trade-offs in indicator design to provide more general guidelines. Effort also focused on the development of a computational tool to predict clutter effects on human performance. The core of the tool is a model of human perception that evaluates HUD images by quantifying the salience of each indicator in the context of other indicators and a standard set of OTW images. The importance of significant OTW objects (e.g., runways and traffic) was likewise evaluated for salience in the context of the HUD indicators.

Results: In an experiment comparing airspeed and altitude indicators with and without gradation marks, gradation marks were found to reduce the amount of attention needed to perform the manual flight task as indicated by an analysis of eye-fixation data. Gradation marks appear to improve the perception of changes in an instrument across eye fixations, reducing the reliance on other instruments. It was concluded that gradation marks are recommended for analog HUD altimeters and airspeed indicators that are used for manual flight. The computational model of human perception developed for use in a clutter evaluation tool demonstrated the ability to quantify various scenes varying in symbol clutter and background texture and color. For a given target image and context, a single number is produced measuring the salience of the target in the context, a number that agrees with subjective impressions of the scene.

Recent Accomplishments: Researchers completed the gradation mark study, establishing the value of gradation marks for counter-pointer instruments. They successfully demonstrated quantification of display clutter using a computational model of human perception, and developed hardware and software for experimental evaluation of high and low clutter tapes for heading, altitude, and airspeed. The development includes implementing the HUD and simulated traffic, upgrading the simulator out-the-window view and physical control console, and upgrading the eye-tracking hardware. (See image, next page)

Primary Investigator: Michael Zuschlag, Volpe National Transportation Systems Center, Cambridge, MA

Airport Surface Information Displays

FAA sponsor Organization: Aircraft Certification Service

Purpose and Rationale: Many avionics vendors are developing surface moving map displays that depict airport surface information pertinent to takeoff, landing, and taxiing operations. The intended function for this application is to: (1) assist flight crews in orienting themselves on the airport surface by enhancing the pilots' awareness of ownship position on the airport surface; and, (2) improve pilot position awareness with respect to taxi operations. The objective of this project is to provide guidance to facilitate the identification and resolution of flight deck human factors issues on airport surface information displays. The information is expected to be of use to FAA evaluators, system designers and manufacturers, and users.

Methodology: A comprehensive reference document that captures human factors issues relevant to the design of airport surface information displays was drafted. Material for the report was obtained in 2003. It was compiled from: (1) discussions with manufacturers studying or developing these displays; (2) participation in industry groups; (3) reviews of specifications and research reports describing a display's features and intended usage; and, (4) a review of FAA regulations and policies. The reference document also contains an industry snapshot which provides a look at surface moving map products being developed to date. In 2004, this document was reviewed by the FAA and revised accordingly.

Results: The surface moving-map document provides a collection of FAA regulations/policy and industry documents containing design guidelines and user interface principles. Topics in the document address general user interface design principles as they are relevant to the surface moving map function, the design of display elements that are commonly depicted on surface moving maps, the depiction of traffic, and the usability of functions. Note that this document contains guidance material, but is not required or regulatory. Two appendices are provided. One appendix is an industry overview, updated in August, 2003, that presents a snapshot of the efforts by manufacturers and research organizations to develop a moving map display with ownship position. For each display, the elements depicted, their method of depiction, and the functionality provided are listed. A second appendix presents a summary of the requirements and recommendations listed in this document. This summary can be used by manufacturers and regulators when conducting human factors evaluations of surface moving map displays.

Recent Accomplishments: A draft of *Human Factors Considerations in the Design and Evaluation of Moving Map Displays of Ownship on the Airport Surface* was submitted to the FAA for review in 2004.

Primary Investigator: Michelle Yeh, Volpe National Transportations Systems Center, Cambridge, MA

Error Management

FAA Sponsor Organization: Aircraft Certification Service

Purpose and Rationale: Human error is considered a contributing factor in 70-80 % of all aviation accidents. Efforts to reduce or eliminate errors through training and design have had only limited success. It is critical also to determine how best to mitigate the negative consequences of errors by supporting their detection, explanation, and recovery. Earlier research on error management focused on the likelihood and circumstances of error detection. Researchers at Ohio State University worked to achieve a better understanding of successful and poor error explanation and recovery and identified ways to better support these two later stages in the error management process. They identified processes and strategies involved in the diagnosis of and recovery from automation-related errors, and they also identified resulting disturbances in the complex environment of the modern flight deck.

Methodology: To identify and analyze processes and strategies involved in successful and poor management of automation-related errors on modern flight decks, a combination of methods was used in a converging operations approach. These methods included a review of existing error management literature, jump seat observations, a survey of glass cockpit flight instructors, and a review of 935 Aviation Safety Reporting System reports that involved management of automation-related errors on a variety of modern flight decks. Researchers also conducted a controlled simulation study of error management on a Boeing 747-400. This presented pilots with a series of challenging events to probe their use of the autoflight system and their related ability to detect, diagnose, and recover from automation-related erroneous actions and assessments and resulting disturbances. Process tracing was used to analyze the interplay between events, feedback, and pilots' actions and reasoning.

Results: Findings indicate that pilots tend not to engage in diagnostic activities following detection of an error. In many cases, gaps and misconceptions in a pilots' model of the automation and/or time pressure – due to delayed detection of the problem – explained the absence of diagnostic activities. Pilots tended to move directly from detection to recovery, where generic strategies – such as repetition of an action or resetting of the automation – or a trial-and-error approach were observed. These strategies tended to be unsuccessful and/or inefficient. Pilots also showed a tendency to rely on high levels of automation for recovering from a problem. Ultimately, pilots managed to complete the flight successfully. However, their difficulties with error management suggest the need for improved feedback that helps anticipate and understand automation behavior, and new training approaches that support the formation of accurate user models.

Recent Accomplishment: The first controlled simulation study of error and disturbance management on modern flight decks was completed using twelve airline pilots. Findings highlight shortcomings of current error management strategies and performance. They also suggest possible improvements in design and training for automated flight decks to ensure that pilots can diagnose and recover effectively from erroneous actions and assessments. Results from this research are summarized in a final technical report.

Primary Investigators: Nadine B. Sarter, The University of Michigan, Ann Arbor, MI; Mark I. Nikolic, The Ohio State University, Columbus, OH

Producing Results – General Aviation Research

Program Manager Dr. William "Kip" Krebs directs general aviation (GA) research that focuses on reducing fatalities, accidents and incidents within the general aviation flight environment. Two of the Administrator's Flight Plan Safety Objectives focus directly on GA – (2) reduce the number of fatal accidents in GA, and (3) reduce accidents in Alaska. The GA environment is defined as all flights that are conducted under Federal Aviation Regulation Part 91, as well as the general aviation maintenance community. Human factors research addresses better methods for detection, classification, and reporting of accidents involving human factors, developing certification and flight standards and guidelines based on human factors research, and identifying and implementing intervention strategies that impact GA accidents.

Research objectives are focused on reduction of weather-related and maneuvering flight accidents, controlled-flight-into-terrain, and pilot field-of-vision capabilities and limitations. Other objectives include loss of primary flight instruments during instrument meteorological conditions, the implications of future technology on human performance, and improving general aviation training.

Human Error and General Aviation Accidents: A Comprehensive, Fine-Grained Analysis Using the Human Factors Analysis and Classification System

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: The Human Factors Analysis and Classification System (HFACS) is a theoretically based tool for investigating and analyzing human error associated with high-risk environments like aviation. Previous research has shown that HFACS can be reliably used with commercial and general aviation accidents/incidents to analyze underlying human factors. Our previous analyses have identified general trends in the types of human errors that have contributed to civil aviation accidents. This project went beyond those trends and identified, among other things, the types of errors committed and the relative importance of each error type in the genesis of accidents.

Methodology: Using records maintained by the National Transportation Safety Board and the FAA, seven pilot subject matter experts used HFACS to determine global human error categories associated with each human causal factor for each aviation accident occurring between 1990-2000. In total, over 17,000 accidents associated with human error were examined, yielding nearly 34,000 causal factors.

Results: Aircrew skill-based errors were the most frequent unsafe act identified within the accident data and were associated with nearly 80% of all GA accidents. This was followed by decision errors (30%), violations (14%) and perceptual errors (6%). Note the percentages do not add up to 100% because accidents are associated with multiple cause factors. The same is true if one examines the seminal error in the chain of events (skill-based errors 61%; decision error 19%; violation 8%; perceptual error 4%). Upon closer examination, the most frequently cited skill-based errors involved directional control on the ground, aircraft control in the air, airspeed, and compensation for winds. The top decision errors involved in-flight planning/decision making, takeoff/landing from unsuitable terrain, fuel related issues, and pre-flight planning/decision making. The top violation involved VFR flight into IMC, which also accounted for the largest portion of fatal accidents.

Recent Accomplishment: The culminating effort of this three-year project involved development of the human factors intervention matrix (HFIX) to complement the HFACS framework. HFIX maps the causal categories of HFACS against five approaches to human factors intervention (organizational/administrative, human/crew, technology/engineering, task/mission, operational/physical environment). A follow-on grant will validate HFIX and assess current FAA GA safety initiatives relative to the HFACS findings and these approaches.

Primary Investigators: Scott Shappell, FAA Civil Aerospace Medical Institute, Oklahoma City, OK; Douglas Wiegmann, Institute of Aviation, University of Illinois, Savoy, IL

An Online Human Factors Analysis and Classification System (HFACS) Searchable NTSB Accident Database Tool

Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: This research will allow field investigators and other interested personnel to correlate and study NTSB accident information in combination with HFACS data. The tool will also help in improving strategies to prevent aviation accidents and incidents. It will improve the speed at which the information is made available by allowing online data entry and verification versus paper-based methods currently in use.

Methodology: An online web based tool was created (http://www.hf.faa.gov/hfacs) to allow for the searching of data. Data is imported from NTSB and HFACS into a large, searchable database. Authorized personnel can query the data using either a basic or advanced methodology. Results can be downloaded in PDF or Microsoft Excel format for post processing.

Results: The tool has not been made available to personnel as yet. We anticipate that the use of the tool will enable greater reduction of aviation accidents and incidents.

Recent Accomplishment: Researchers completed search engine technologies for the web site. The advanced query tool gives personnel the flexibility to search on a large variety of criteria versus other search engines that are available. The user does not need an in-depth knowledge of database searching techniques to conduct a complex query.

Primary Investigator: Rob Heckart, CSSI, Inc., Washington, DC

Visibility in the Aviation Environment

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: This research will develop research and education materials for reducing accidents caused by problems of visibility in the air and on the ground. There are four related areas of concern: (1) continued flight into reduced visibility and/or "flat light"; (2) failure to detect other aircraft and obstacles in the air and on the ground; (3) failure to utilize resources; and, (4) need for improved education and training for areas of concern 1-3. Accidents related to visibility account for a large portion of the total fatalities in aircraft. Visibility issues range from continued flight into instrument meteorological conditions (IMC) resulting in controlled flight into terrain (CFIT), runway incursions and ground-based accidents during low visibility conditions, and midair collisions with ground-based objects or other aircraft. Mid-air collisions are often due not only to reduced visibility, but also to background conditions that mask the target. Many of these accidents occur in clear skies. In most situations, there appears to be a failure on the part of pilots to recognize unsafe visual conditions and take appropriate action. In many accidents, pilots did not avail themselves of available technology installed in the aircraft, or ATC services. Further research aimed at understanding visual limitations under conditions of low visibility and decreased detection is needed.

Methodology: Images from the cockpit are collected with a high quality digital camera. These images are analyzed by applying a sparse coding algorithm. The weighting coefficients from the derived basis functions are compared with those from land-based images. Visual detection experiments are conducted using images with different function weightings, and detection performance is correlated with the weightings to determine which statistics correspond to poor detection. These data form the basis for instructional materials that help pilots recognize visual conditions under which aircraft or terrain detection is difficult. Instructional materials include training in visual acquisition - judgments of distance, direction, orientation, and relative altitude based on size and angular position. Training also includes recognition of flat light conditions and reduced contrast from atmospheric effects.

Results: Preliminary analysis of aviation images indicate a lower proportion of basis function contribution that is oriented along the horizontal and vertical meridians than those from land-based images. Basis function sets derived from aviation images differ from those derived from land-based images.

Recent Accomplishments: The research team has completed construction of the flight simulator with wrap-around visual display. An information card has been produced showing the apparent size of aircraft at different distances intended for instruction and quick reference use in the cockpit. The first phase of programming on an interactive instructional series has been achieved to help pilots learn apparent size, orientation, and visual characteristics of aircraft located throughout the aviation visual environment.

Primary Investigator: Michael A. Crognale, University of Nevada - Reno, Reno, NV

Assessment of Proposed Traffic Symbol Set

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: Recent technological advances (e.g., ADS-B, TIS-B) afford the capacity to display traffic in the cockpit. More information on traffic is now available than in previous systems (e.g., TCAS), and some of this information may be coded in the traffic symbols on the display (e.g., by varying shape and color of the symbols). There is no consensus among manufacturers for the traffic display symbol set, prompting FAA Aircraft Certification to propose an acceptable set in an appendix to a draft Advisory Circular (AC) Airworthiness and Operational Approval Considerations for Traffic Surveillance Systems. The purpose of this project is to determine if the proposed symbol set is acceptable when displayed on low-end flight deck displays. Specifically, the assessment will determine the symbols' recognizability and propensity to be confused with one another (discriminability).

Methodology: The study is a descriptive psychophysical experiment. Ten pilots were recruited from a local airport. All had normal color vision and adequate visual acuity. The 19 symbols in the symbol set were presented one at a time on a bench-mounted aviation multifunction display (MFD) for 250 ms. The MFD was illuminated with approximately 94 kLx of light using a spotlight to simulate sun-shaft illumination. For each trial, each participant was shown a symbol in isolation and asked to select the perceived symbol from a matrix of 19 possible symbols presented on a laptop equipped with a touch screen. Error rates and reaction time were recorded.

Results: When viewed at a distance and angle approximating that found in a general aviation cockpit, most symbols were correctly recognized at least 92% of the time. The exception was symbols intended to indicate a selected state; these were correctly recognized as low as 83% of the time. In the proposed symbol set, a selected state was indicated by outlining the symbol. The data suggest that this convention increases the likelihood that participants will confuse symbols indicating non-proximal traffic (represented by a hollow symbol) with symbols indicating proximal traffic (represented by a solid symbol).

Recent Accomplishments: Completed a study on symbol discrimination, providing data to the FAA that directly impacts the content of an advisory circular in preparation**.**

Primary Investigator: Michael Zuschlag, U.S. Department of Transportation, Volpe National Transportation Systems Center, Cambridge, MA

Comparison of the Effectiveness of a Personal Computer Aviation Training Device (PCATD), a Flight Training Device (FTD) and an Airplane in Conducting Instrument Proficiency Checks

FAA Sponsor: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Under one Federal Aviation Requirement, pilots must maintain instrument cur-rency through activities conducted in an airplane or in an approved FTD. If pilots fail to meet this requirement within a 12-month period, they must undergo an instrument proficiency check (IPC) with a certi-fied flight instructor. PCATDs are not currently approved for administering the IPC nor is there any evidence that PCATDs are effective for administering an IPC. This project compares the performance of pilots receiving an IPC in a PCATD, an approved FTD, or an airplane. These comparisons will help determine the effectiveness of the PCATD to administer an IPC and the appropriateness of the current rule regulating IPCs in an FTD.

Methodology: Seventy-five instrument pilots were assigned to either an FTD, PCATD or airplane group (25 subjects in each group). All participants received a familiarization flight and a review of the systems and instrumentation in the FTD, the PCATD and the airplane prior to being assigned to an experimental group. Following the familiarization flights, all 75 pilots receive a baseline IPC flight either in the FTD, PCATD or an airplane (IPC #1) according to the group to which they were assigned. IPC #1 was flown with a certified flight instructor/instruments (CFII) who served as a flight instructor and experimental observer. All subjects were then given a second IPC in the airplane (IPC #2) with a second CFII. The participants were required to refrain from instrument flight following IPC #1 until IPC #2 was completed.

Results: As of August 2004, all 75 (an increase 21 from last year) of intended pilots completed IPC #1 and all of the 75 pilots (and increase of 24 from last year) completed the study. There were few differences between groups for the number of subjects who passed IPC#1 and IPC#2. A total of 24 pilots passed IPC #1 (32%) and a total of 42 pilots passed IPC #2 (56%). The pass/fail rates for IPC #2 show fewer failures for each group and for the total when compared to the pass/fail rates for IPC #1. Statistical analyses indicated no overall treatment effect (assignment to group) and no statistical differences between any of the groups.

Recent Accomplishment: Based on the results of the study, it is recommended that the PCATD be approved for administering IPCs.

Primary Investigator: Henry L. Taylor, Institute of Aviation, University of Illinois at Urbana-Champaign, Savoy, IL

Credit for Instrument Rating in a Flight Training Device or Personal Computer

FAA Sponsor: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Current FAA policy allows pilots to complete 10 hours of instrument training in an approved Personal Computer Avi-ation Training Device (PCATD). The intent of this research effort is to determine the amount of instrument training that is effective in flight training devices (FTDs) and PCATDs compared with training in an aircraft. To evaluate transfer of training, the performance of subjects trained on instru-ment tasks in an FTD and PCATD and later trained to criterion in an airplane must be compared to the performance of subjects trained to criterion only in the airplane. This study used an incremental transfer of training research design to measure the effectiveness of a FTD and a PCATD to determine the point at which addi-tional training in an FTD or a PCATD was no longer effective. The results will enable certifica-tion personnel to determine what credit to award for different classes of flight training devices within an instrument training curriculum.

Methodology: In the initial approved proposal, a total of 180 pilots (30 in each of six groups) were scheduled to participate in the study. The subjects (Ss) are enrolled in the instrument training pro-gram at the University of Illinois. Due to budget constraints in the 2nd and 3rd years, the number of Ss was reduced to 120 (20 Ss per group). The design has four FTD groups, a PCATD group and an airplane (control) group trained only in the airplane. The number of subjects in each group is expected to range from 16-20 in 2005. The four FTD groups received 5, 10, 15, or 20 prior hours of training in an FTD, the PCATD group received five prior hours in the a PCATD, and the control group received all its training in an airplane. The dependent measures, which were recorded in the airplane, were trials to criterion for selected instrument tasks, time to complete a flight lesson and dual time to a stage check or an instrument proficiency check. Trials/ time saved for the FTD groups and the PCATD group compared to the airplane group was a measure of the effectiveness in the devices. The results were evaluated to determine how to optimize the value of training time in the FTD or PCATD.

Results: As of August 31, 2004, all planned Ss (124, an increase of 59 from last year) have taken the final check ride in the basic instruments course. The mean completion time for the airplane group was greater (22.35 hours) than any of the five experimental groups (range from18.31-20.87 hours). A similar trend has been found for the advanced instruments students. Ninety-one Ss compared to 31 in last year's report had completed the course and check ride. The airplane group required an average of 26.02 hours to course completion, while the hours of the experimental groups ranged from 25.77- 20.11 hours to completion. Statistical analy-ses based on current data shows no statistical differences between the control and the four experimental groups that received training on instrument tasks.

Recent Accomplishment: The trend suggests that FTDs and PCATDs are effective for teaching instrument tasks and for cross country flight.

Primary Investigator: Henry L. Taylor, Institute of Aviation, University of Illinois at Urbana-Champaign, Savoy, IL

National Airspace Human Factors Integration Plan for Unmanned Air Vehicles: An Evaluation of Human Factors Research Issues

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Unmanned aerial vehicles are quickly becoming a part of the national airspace system as they transition from military and hobbyist applications to mainstream flight applications such as surveillance, cargo hauling, and crop dusting. Before unmanned aircraft can be fully integrated into the National Airspace System (NAS), research is required to address a variety of issues related to the human factors of UAV operation. These are likely to include the selection and training of UAV operators, the design of displays and controls for UAV operators, the size of crew complement, the allocation of responsibility among human crew members and automated systems, and the interaction of UAVs with air traffic controls systems. The goal of this project is to survey and integrate findings from the existing literature on the human factors of UAV operation, and to identify specific research questions that remain for the FAA to address in preparation for the impending integration of UAVs into the NAS.

Methodology: Investigators are reviewing the existing literature on UAV operation, UAV research, and UAV design.

Results: The team has gathered and summarized extant literature on the human factors of UAVs, identifying the issues that have been studied and noting the gaps that remain in our knowledge of human-UAV interaction. Important topics for future research will include the design of information displays to compensate for the dearth of sensory cues available to a UAV operator; the allocation of responsibilities to human operators and automated support systems under normal operations and during emergencies; and the training and selection of UAV operators.

Primary Investigators: Jason S. McCarley and Christopher D. Wickens, Institute of Aviation, University of Illinois at Urbana-Champaign, Savoy, IL

A Summary of Unmanned Aircraft Accident/Incident Data: Human Factors Implications

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Available reports regarding unmanned aircraft (UA) reliability have noted that the accident rate for UA is, in general, much higher than that of manned aircraft. The purpose of this research is to review all available information on military UA accidents to determine how human error played a role in those accidents, and also identify which human factors were most involved in the accidents.

Methodology: Accident data were collected from 328 UA accidents across the US Army, Navy, and Air Force. In addition, other reports summarizing UA accident data were reviewed for inclusion in the data. Classification of the accident data was a two-step process. In the first step, accidents were classified into broad categories of human factors, maintenance, aircraft, unknown, or a system-specific category pertinent to that particular UA system. Accidents could be classified into more than one category. In the second step, those accidents determined to be human factors-related were classified according to specific human factors issues based on the stated causal factors in the reports, the opinion of safety center personnel, and personal judgment of the author.

Results: The percentage of involvement of human factors issues varied across aircraft systems from 21% to 68%. For most of the aircraft systems, electromechanical failure was more of a causal factor than human error. Mishaps attributed at least partially to electromechanical failures ranged from 33% (Global Hawk) to 67% (Shadow). One critical finding from an analysis of the data is that each of the fielded systems is very different, leading to different kinds of accidents and different human factors issues.

Recent Accomplishment: For the most part, design of the user interfaces of these systems is not based on previously established aviation display concepts. These aircraft are not "flown" – they are "commanded." Only one of the aircraft reviewed (Predator) has a pilot/operator interface that could be considered similar to a manned aircraft. The other UA are commanded through the use of menu selections, dedicated knobs, or pre-programmed routes. This is a paradigm shift that must be understood if appropriate decisions are to be made regarding pilot/operator qualifications, display requirements, and critical human factors issues to be addressed. Civil Aerospace Medical Institute personnel participated in the operational test of an unmanned aircraft at King Salmon, AK. A report summarizing see-and-avoid issues encountered during the operational test was written. Also, CAMI personnel attended a workshop on the human factors of UAVs held in Phoenix, AZ.

Primary Investigator: Kevin W. Williams, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

General Aviation Private Pilot Survey: Designated Pilot Examiner Program Assessment

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: In order to meet safety objectives set for in the Administrator's Flight Plan (reduce the number of fatal accidents in general aviation), the General Aviation (GA) and Commercial Division plans to improve the Designated Pilot Examiner (DPE) program. A DPE administers a practical test to evaluate pilot knowledge and skill to perform a task. Problems arise when application of the DPE test criteria vary between examinations, examiners, or examinees. Two surveys are being conducted to determine the effectiveness of the examiner oversight program. One survey will be administered to all newly certified general aviation single engine land private pilots. In order to provide a balanced perspective of the practical test standard process of single engine land certification, it was proposed that DPEs be given the opportunity to comment on the process as well. A second survey will be administered to all Designated Pilot Examiners across the United States.

Methodology: Newly certified GA pilots from all Flight Standards District Offices (FSDO) will receive an anonymous and voluntary survey. The Civil Aerospace Medical Institute (CAMI) will supply FSDOs with copies of surveys to mail to traditionally registered pilots. CAMI will mail surveys to pilots registered through the Integrated Airmen Certificate and/or Rating Application database. CAMI will also send all DPEs an anonymous and voluntary survey. In an attempt to maximize response rates, the survey will have an attached cover letter explaining the purpose of the survey, and asking for feedback regarding flight training and testing experiences. DPEs will be assured that the survey is completely anonymous and voluntary, and that if any of the questions make them feel uncomfortable, they should skip them. Returned surveys will be scanned into a database through the use of Teleform software. Summary reports for the surveys will be created for each region that has at least eight respondents.

Results: Two surveys will be conducted to determine the effectiveness of the examiner oversight program. One survey will be administered to all newly certified GA single engine land private pilots. A second survey will be administered to all Designated Pilot Examiners..

Recent Accomplishment: CAMI is working with several members of the DPE improvement team to identify the best approach regarding survey questions and obtaining pilot names.

Primary Investigator: Carla Hackworth, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Electronic Primary and Multi-function Flight Displays for GA; Certification Criteria and Usability Assessments

FAA Sponsor Organization: Small Airplane Directorate, Programs and Procedures

Purpose and Rationale: This research identifies factors salient to design and certification of primary-flight displays (PFD) and multi-function displays containing terrain representations and flight guidance cues. It quantifies their effects on pilot performance (flight technical error, procedural performance, terrain awareness, usability). The questions involved not only anticipated certification submissions, but also displays being installed for the Capstone program and other displays in the certification process. The scope includes any platform presenting this information in the cockpit, whether in a head-down, head-up, or head-mounted display. Specific concerns involved: (1) salience of the zero-pitch line when a terrain background was present; (2) whether the juxtaposition of the reference and terrain horizon would negatively impact pilot performance when recovering from unknown attitudes; and, (3) what impact auxiliary guidance cues might have on recovery performance.

Methodology: Forty pilots participated in the study, each group of eight using a different PFD terrain depiction (none, full-color terrain, brown terrain) and guidance indications (either pitch and roll arrows or none). Note: see image, next page. Terrain imagery was based on variable-size textured polygons. Pilots performed eight warm-up recovery maneuvers with an electronic attitude-direction indicator on the PFD, followed by 16 recovery maneuvers using the PFD that was assigned to their group. The maneuvers consisted of pitch up (20°), pitch down (15°), roll left or right (60°), pitch up (20°) and roll left or right (60°), and pitch down (15°) and roll left or right (60°). Half of the headings ended the recovery facing mountainous terrain higher than the aircraft altitude and half ended the recovery facing terrain lower than aircraft attitude. Pilot recovery times and initial response times were recorded for each trial.

Results: Analysis of variance indicated there were no significant differences between the displays, and follow-up analyses indicated no differential effects by maneuver. Additional trials (mountainous terrain ten degrees above the zero-pitch line) performed by those flying terrain-depicting formats also failed to produce any significant premature halts at the terrain horizon rather than the zero-pitch line. An inverted trial was flown from approximately 165 degrees of bank, with no apparent or consistent effects of display type on pilot performance. It appears that presence of a zero-pitch line of sufficient contrast (white with black borders) to all backgrounds allows pilots to adequately perform recoveries from unknown attitudes without interference from background terrain. Although the directional-guidance arrows produced a positive qualitative response, participants did not produce any significant quantitative difference in performance.

Recent Accomplishments: Findings were briefed to the Human Factors Coordinating Team and the sponsor. The briefing contained data specific to questions raised about this type of display by Aircraft Certification, and that bore directly upon present certification practices for terrain-depicting PFDs. Suggestions were presented on future applications for certification. A paper reporting the results was proposed to the 2005 International Symposium on Aviation Psychology.

Primary Investigator: Dennis B. Beringer, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Producing Results – Vertical Flight Research

Program Manager Dr. William "Kip" Krebs directs vertical flight human factors research that identifies issues associated with helicopter operations within the National Airspace System. It is a relatively new area that addresses certification and regulation of civilian flights with night-vision devices, simultaneous non-interfering operations, and the implications of tilt-rotor controls. Other research areas include head-up displays for general aviation rotorcraft, low-speed helicopter/power lift displays, and vertical flight instrument flight rules approach lighting requirements.

Quantify Precision Visual Flight Rules and Simultaneous Non-Interfering Routes for Rotorcraft Operations

FAA Sponsor Organization: Flight Standards Service, Flight Tech & Procedures Division

Purpose and Rationale: This research is determining the ability of pilots operating under Visual Flight Rules (VFR) to stay within narrow horizontal limits specified by Global Positioning System (GPS) coordinates. To the extent that GPS systems enable pilots to adhere more closely to specified routes, this type of flight is known as Precision Visual Flight Rules (PVFR). Operation under PVFR may permit safer and higher-volume operation in congested areas with fixed-wing traffic, which is referred to as Simultaneous Non-Interfering (SNI) operation. In this study by NASA and the Navy Post Graduate School, researchers seek to measure the size of route deviations made during PVFR flight. Additionally, they are measuring gaze behaviors to determine how the frequency of monitoring the GPS receiver and out-the-window landmarks affect navigation performance. The results will be used to develop guidelines for new regulations and training procedures for the use of GPS systems.

Methodology: A series of flight tests were flown in the Tullahoma, Tennessee area in the fall of 2003. A single 8mm videocassette was used to record four video streams, one audio stream, and GPS data sampled at 1 Hz. Two of the four video streams came from cameras mounted to a goggle worn by the pilot, one viewing the pilot's right eye (providing head-relative gaze), and another looking forward (providing the view in the head direction, and the position of the head). The remaining two cameras were mounted to the cockpit interior, one providing a frontal view of the pilot, while the other provided an over-the-shoulder view. Video data was analyzed off-line in the laboratory using machine vision software. In a parallel effort, a detailed model of the Tullahoma airspace has been developed that will be used in a flight simulator to replicate the results of the flight tests. Both navigational performance and behavioral measures such as gaze will be collected in the simulator, and compared with the flight data to determine the extent to which the simulator approximates actual flight.

Results: Preliminary analysis of navigation performance is complete and may be viewed at http://vision.arc.nasa.gov/personnel/jbm/home/projects/sni/sni.html. Generally, pilots are able to adhere quite closely to the specified route. One subject, however, showed strikingly different behavior when flying at night. His flight track showed large looping oscillations. This difference indicates a need for training in using feedback from the GPS receiver to set and maintain a course. Analysis of the behavioral data captured on the videotape is not complete, but most of the necessary software has been implemented and preliminary results may be viewed on the website. Preliminary eye tracking results are available at http://www.hf.faa.gov/docs/508/docs/VF-PVFRflight.mpg

Recent Accomplishments: Development of hybrid head-post estimation procedure merging data from images of the pilot's face with images from the head-mounted scene camera, and construction of the simulator database are completed.

Primary Investigators: Jeffrey B. Mulligan, NASA-Ames Research Center, Moffett Field, CA; Rudoph P. Darken, Joseph A. Sullivan, Naval Postgraduate School, Monterey, CA

Night Vision Imaging System Lighting Compatibility Assessment Methodology

FAA Sponsor Organization: Flight Standards Service, Flight Technologies & Procedures Division

Purpose and Rationale: Aircraft cockpit lighting can interfere with the operation of night vision goggles (NVGs). The accepted military practice to determine whether or not a lighting system is NVG compatible is to compare the visual acuity through the NVGs with and without the cockpit lighting activated. This procedure requires expensive illumination sources and radiometric measurement equipment that can cost in excess of $100,000. An inexpensive alternative method to assess compatibility, that provides the same quality of results as the military method, is needed for civilian applications. The first part of this project successfully investigated equipment, methods, and procedures that could result in an acceptable, inexpensive alternative method. A method using an inexpensive illuminator validated with an inexpensive illuminance meter was devised and successfully demonstrated in a human-use study. An alternative, objective method using the same inexpensive illuminance meter was also included in the study and showed great promise. A second human-use study was conducted to compare the inexpensive, illuminance meter-based assessment method with the visual acuity-based method.

Methodology: Six trained subjects participated in this second human use study. All subjects had been trained and participated in the first study. Subjects were instructed in the specific methods of conducting lighting compatibility assessments using visual acuity, and also how to use the illuminance meter to measure the average light output of the NVGs. The procedure was exactly like the military procedure in that each subject would determine what acuity pattern was resolvable when viewing through the NVGs with the cockpit lighting off. Then the cockpit lighting was turned on and the subject would determine if he/she could still see the same element. If there was a loss in visual acuity, then, according to the published procedures, the cockpit lighting would be deemed incompatible. This procedure was repeated using the cockpit lighting simulator set for six different radiance levels for each of two viewing conditions. The two viewing conditions were: (1) viewing through reflections in a simulated windscreen; and, (2) viewing through the simulated windscreen with no reflections. For the objective method, the illuminance meter was attached to the end of the NVG to obtain an average light output reading. The NVG was then pointed out of the simulated windscreen as a pilot would be when looking outside. If the illuminance meter reading increased by more than a certain criterion level when the cockpit lights were turned on (compared to being off) then the cockpit light was deemed unacceptable. Probability of rejection as a function of radiance level curves were then generated for both the visual acuity-based method and the illumiance-level based method.

Results: The results indicate the objective method can provide a much better, more definitive method of accepting or rejecting an NVG cockpit lighting system if used in conjunction with a visual inspection method to insure objectionable reflections are minimized or eliminated.

Recent Accomplishment: The second study has been completed and the data analyzed.

Primary Investigators: Alan Pinkus, Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, OH; Lee Task, Task Consulting, Dayton, OH

Producing Results – Air Traffic Control/Technical Operations Research

Under the leadership of Program Manager Dino Piccione, the ATO Air Traffic Control/Technical Operations (ATC/TO) human factors program provides our customers in the ATC operational and system development communities with products that specify the capabilities and limitations of humans in the context of ATC systems. These outputs are shaped by the program's research on human performance and other human-system integration issues associated with the concept of operations, system architecture, acquisition, operation, and maintenance of ATC systems. Our simulations and work station prototypes provide a proving ground for advanced concepts to determine their viability in the future National Airspace System in terms of human performance. Improvements in how errors are investigated and reported will foster effective safety interventions. New specifications for the design of TO workstations and displays, and recommendations to improve the communications and coordination process in TO organizations will help to optimize human performance. Continuing research is increasing our understanding of how to effectively deal with regulations associated with workforce attrition due to retirement.

Air Traffic Control
Technical Operatio

Collocation of URET/TMA/CPDLC (URET/TMA/CPDLC Simulation)

FAA Sponsor Organization: AOZ-40, ATO-P R&D

Purpose and Rationale: The Federal Aviation Administration (FAA) Free Flight Program individually deployed the User Request Evaluation Tool (URET), Traffic Management Advisor (TMA), and Controller-Pilot Data Link Communications (CPDLC) to a limited number of Air Route Traffic Control Centers (ARTCCs). Before deployment expands nationwide, it was important to identify any potential human factors issues that may arise due to the collocation of these tools at the controller's workstation. In this paper, we present the results of a high fidelity human-in-the-loop simulation we conducted to evaluate the impact of URET, TMA, and CPDLC collocation on air traffic controllers. This series of studies examined collocation issues with a "stovepipe" independent configuration where none of the tools were integrated or directly communicated with each other.

Method: The FY04 effort completed analyses and reporting of two studies. In the FY03 project, researchers conducted a human-in-the-loop simulation consisting of three experiments to assess the human factors issues of collocating URET, CPDLC and TMA. Twelve controllers participated. Six controllers were trained and current with URET. Six were trained and current with TMA. The FY04 project involved completing analyses of data on a single controller sector operation, as well as teamwork and communication issues.

Results: The most prominent human factors issue identified in this study was that controllers had difficulty accessing important information on the Dside display when URET and CPDLC were both operational (i.e., display clutter). The display clutter problem resulted from a "stovepipe" independent deployment of both URET and CPDLC and having to manage the multiple windows associated with these tools. Good human factors design principles prescribe that users must have immediate access to important information and that critical information should never be covered. A "stovepipe" independent deployment of these tools will result in impaired access to timely information. The results of this study indicated that better human factors efforts should be made towards integrating the information from URET, TMA, and CPDLC. In a single person sector configuration, controller workload ratings using NASA-TLX indicated that mental demand, temporal demand, effort, and frustration increased when URET, TMA, and CPDLC were operational.

Recent Accomplishments: (1) Completed data collection on 16 participants (FY03). (2) Completed 2 technical reports. (3) Papers accepted for presentation at the Air Traffic Controllers Association Annual Meeting and the 23rd Annual Digital Avionics Systems Conference. (4) A Technical Note in preparation examining the effects of collocation of the three tools on sector teamwork and communications.

Primary Investigator: Pam Della Rocco, Randy Sollenberger, FAA William J. Hughes Technical Center, Atlantic City, NJ

Dynamic Resectorization

FAA Sponsor Organization: AUA-200, ATO-P R&D

Purpose and Rationale: Current airspace structure is rigid and does not allow for flexible dynamic boundary adjustments. Dynamic resectorization of airspace boundaries is adaptive and can efficiently handle heavy traffic situations, shifting weather conditions, status changes in special use airspace, and user-preferred routes. Dynamic resectorization will reduce aircraft delays, decrease fuel consumption, and lower operating costs for the airline industry. The direct benefits to controllers are to offset heavy workload and reduce coordination and communications. However, dynamic resectorization may not be effective for all traffic situations. It is important to identify situations where dynamic resectorization may be beneficial and situations where it may be disruptive, as well as alternatives to dynamic resectorization. This will allow ATC to maximize the use of finite airspace as traffic patterns demand by offsetting heavy workload, and thereby, increasing safety and capacity. This project will result in a report with recommendations for an approach to assess dynamic resectorization based upon empirical data.

Method: There are different approaches to implementing dynamic resectorization using current and future technologies. Concepts range from a current practice of coordinated consolidation of airspace by TRACONs and ARTCCS into large TRACONS during particularly heavy arrival times, to completely dynamic remapping of any sector at any time. Some methods may be less disruptive and more effective than others. Full dynamic flexibility may be more than is actually needed and may not be cost effective. In the first phase, we will conduct a literature review on the current status of the dynamic resectorization concept by examining the past few years of research conducted by MITRE/CAASD, MIT Lincoln Labs, and others. We will visit field facilities and identify sectors and traffic patterns that can benefit from dynamic resectorization. Working with operational controllers and TMU experts in structured interviews, we will identify as many different ways as possible in which "dynamic resectorization" could be accomplished to improve efficiency over current procedures. We will explore whether or not there are options to moving sector boundaries. These will be captured and published in a technical report.

Results: In Progress.

Recent Accomplishment: A draft FAA Technical Note is in preparation.

Primary Investigator: Pam Della Rocco, Randy Sollenberger, FAA William J. Hughes Technical Center, Atlantic City, NJ

Future En Route Workstation

FAA Sponsor Organization: AUA-200, ATO-P R&D

Purpose and Rationale: Systems engineering of the future En Route Workstation is required to ensure that the workstation is well designed and integrated around the controller's job. There is a requirement for a series of human factors assessments designed to provide empirical, controller performance data addressing key questions about aspects of the future En Route Workstation that can serve to guide the systems engineering effort. The Agency's ERAM and future En Route programs will benefit from having data at hand to guide management decisions on design of the next En Route Workstations. We will deliver two research reports and empirical controller performance data. One will assess a conflict probe on the R-side. The other will address additional human factors issues of optimizing the workstation.

Method: The approach begins with the FAA's TSD concepts and the projections of 60% increase in traffic levels. We also assume that by 2015, we will be in the middle of a transition to anticipated capabilities on both the cockpit and groundsides of the system. During previous work we have prepared our simulation environment for a fully controlled experiment, in which we identified critical information and functionality of existing automation available to controllers in the 2015 NAS target. The workstation CHI functionality and display of information is independent of existing automation tools. The future workstation concept's goal is to minimize the number of steps and the amount of time an ATCS needs to either retrieve from or input data into the system through application of best human factors principles.

Results: The results of the investigation have been the development of workstation concepts based upon application of human factors principles to ATC job requirements. A simulation infrastructure presents the concepts to allow for a human-in-the-loop simulation.

Recent Accomplishment: The principal investigator convened quarterly meetings and early user involvement events of controllers to apply human factors guidelines to the development of the experimental workstation.

Primary Investigator: Pam Della Rocco, Ben Willems, FAA William J. Hughes Technical Center, Atlantic City, NJ

Human Factors Issues of Achieving the Target System Description

FAA Sponsor Organization: AUA-200, ATO-P R&D

Purpose and Rationale: Both the FAA and the RTCA have presented views of the future ATC system in the 2015 time frame. The FAA needs to identify human factors issues and examine enabling concepts to make the transition to the future vision of the NAS established in the TSD. Understanding the gaps in the knowledge will ensure that we can successfully mitigate problems before they arise. We will deliver a technical note that maps the human factors issues and enabling concepts onto the current TSD vision of the NAS.

Method: Researchers on this project will conduct an in-depth examination of the future of the NAS. We will examine the written documents on these views and identify human factors issues and enabling concepts to be considered as we transition to these future views. Through a rigorous, analytical approach, we will work to uncover the human performance dependencies embedded in moving from the current system to the future, as well as enabling pathways through automation, workstation and job design. We will map the impact of the operational improvements on the human performance factors and map human factors strategies for system design to mitigate the potential for excessive workload or information overload. In addition, we will collaborate with Human Factors Research and Engineering Division, CAMI and Volpe to incorporate their assessments of human factors issues, such that this work may serve to support evolution of the ATC research program.

Results: In progress

Recent Accomplishment: A FAA Technical Note is in preparation to document the human factors issues and enabling concepts.

Primary Investigator: Pam Della Rocco, Ben Willems, FAA William J. Hughes Technical Center, Atlantic City, NJ

Tower Electronic Flight Data Handling

FAA Sponsor Organization: ATB-230, ATO-P R&D

Purpose and Rationale: Currently Tower controllers use paper flight strips to track aircraft and document ATC changes. With the concept of SWIM in the Target System Description (TSD), flight information will be available everywhere. A change from paper to electronic media would facilitate more timely information on flights being both presented to the controller, as well as entering timely information, which is not presently entered into the NAS. Technology is advancing and electronic strips are already seen in en route radar facilities as a function of URET. It is critical to improve flight information handling in the NAS from the Tower to ensure that critical flight status information is available not only to controllers in the Tower, but also to controllers upstream in a timely, efficient manner. Electronic data handling is required to efficiently and optimally manage information flow and meet the expectations spelled out in the TSD. This project will deliver a laboratory infrastructure to support empirical assessment of electronic data handling in the Tower environment.

Method: This study will be a multiyear approach to assess the utility of adding electronic flight data handling capability to the Tower controllers' environment. This project is linked to the current field study at the Civil Aerospace Medical Institute (CAMI) research. We will base our work on their findings and recommendations. We will examine flight data information requirements of Tower controllers as well as examine integration issues with other flight data elements in order to aid the controller's decision making. We will initially conduct a literature review of the use of flight strips in the Tower environment, as well as upgrade the laboratory infrastructure. We will then, in subsequent years, directly compare electronic data handling to the current paper strips to assess the potential for improved information flow both to the controller, as well as data entry into the NAS, which is currently not entered. We will examine how the addition of the electronic information affects team communications and errors, such as runway incursions in future human-in-the-loop simulations.
Results: In progress

Recent Accomplishment: The principal investigator developed a blueprint of the literature review entitled "Electronic Flight Data in the ATCT."

Primary Investigator: Pam Della Rocco, Todd Truitt, FAA William J. Hughes Technical Center, Atlantic City, NJ

Weather Information Needs in the TRACON Environment

FAA Sponsor Organization: ATB-230, ATO-P R&D

Purpose and Rationale: In the NAS, weather reportedly causes over 70% of all delays. For several years, researchers and air traffic control personnel have debated how to best use weather representations on operational ATC displays to optimize traffic flow around adverse weather. This research program addresses controller weather information needs and weather display designs.

Methodology: In the first project phase, researchers completed a literature review on controller and pilot weather information needs and the current use of tactical weather displays. In a second project phase, researchers performed a Cognitive Work Analysis to assess controller/pilot weather information needs and the flow of weather information within the terminal domain. Using this information, researchers developed a simulation display capability that allows empirical evaluations of advanced weather information and display formats. Researchers also developed dependent system measures for the effect of advanced weather information on efficiency, tactical operations, and how display location of weather information affects controller workload. Currently, researchers are preparing weather scenarios for human-in-the-loop simulations beginning in August 2004.

Results: The literature review revealed that very little research has been conducted on weather information needs for TRACON controllers. Researchers suggest, however, that weather display principles that minimize controllers' mental integration of weather data should be used for tactical displays. The results from a Cognitive Work Analysis revealed that for controller operations, the highest impact ratings were for thunderstorms, snow and ice, and airport reconfiguration due to changing winds. The analysis also revealed several information needs for the TRACON controller. Specifically, there is a lack of a graphical display of weather areas with short-time forecast (10-20 minute) capabilities at the controller workstation. This information is especially important for the controller during thunderstorms. There is also a lack of weather information from adjacent airports. During conditions of low ceiling and poor visibility, controllers must often divert Visual Flight Rules (VFR) flights to satellite airports. Without accessible information regarding the conditions at these airports, controllers experience increased workload due to an increase in communications and poor weather situation awareness.

Recent Accomplishment: (1) A cognitive work analysis of TRACON controller weather information needs – FAA Technical Note. (2) A paper describing the Weather Information Display System and display principles for advanced weather information - Journal of Air Traffic Control.

Primary Investigator: Pam Della Rocco, Ulf Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Final Approach Spacing: An Assessment of Self-Spacing Concepts from the Ground Side

FAA Sponsor Organization: ATO-T

Purpose and Rationale: Future visions of the increasingly congested National Airspace System include concepts in which pilots have the responsibility for merging and spacing their aircraft behind other aircraft. In the terminal environment, pilot self-spacing may enable aircraft to safely maintain minimum separation from leading aircraft, thus maximizing arrival rates to the runway. However, new technologies and procedures will be required to support the implementation of these concepts. This project will assist in developing a successful air traffic controller workstation that will support pilot self-spacing operations.

Method: There are three elements of the FY04 methodology. First, the researchers will participate in an international work group to define applications of available technology to enable pilots to perform self-spacing operations. Second, the researchers will collect and review the literature related to pilot self-spacing, with the focus on identifying issues that require additional research, especially in the terminal environment. Third, the researchers will develop a test plan to address those issues.

Results: The international workgroup is refining ten applications, two of which are particularly relevant to this project. One is entitled Enhanced Sequencing and Merging Operations and the other is entitled Enhanced Visual Separation on Approach. Both applications call for pilots to use onboard displays of traffic information to identify traffic to follow and to maintain a prescribed time-based spacing from the lead aircraft. The majority of the relevant literature has been conducted in the en route environment, not in the terminal environment. However, there are a number of issues to be resolved, which include information requirements for controllers, defining acceptable communication protocols, and addressing mixed equipage issues, degraded operations due to weather conditions, and recovery from system failures.

Recent Accomplishments: The researchers have participated in meetings and teleconferences to define the operational applications. They have collected and reviewed over 80 reports and documents related to pilot self-spacing, and have held discussions with numerous researchers in the field. A draft literature report is nearing completion; it will describe the prior research in the self-spacing area and identify issues requiring further research.

Primary Investigator: Pam Della Rocco, D. Michael McAnulty, FAA William J. Hughes Technical Center, Atlantic City, NJ

Human Factors Design Criteria for the Design and Procurement of Non-Keyboard Interaction Devices (NKIDs)

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: In the last 5 years, the number and type of input devices has increased dramatically (see image, next page). When the Human Factors Design Standard (HFDS) was originally published, a mouse was a new way of interacting with computer systems. There was little talk of an ergonomic mouse or scrolling mouse wheels, and touch screens were not common. Now, the mouse is one of the most common interaction devices, there are multiple different touch screen technologies available, and even voice input has become a common interaction method. As new systems are being built, acquisitions personnel seek advice on what interaction device is most appropriate for user needs. The HFDS needed to be updated to provide accurate information for informed decisions.

Method: The first phase of the project involved review and verification of information in the current HFDS chapter on input devices. Researchers then identified new source material and performed a systematic evaluation of literature. They extracted relevant material from the literature and wrote guidelines in the form of should and shall statements. The amount of new information led to a reorganization of certain topic areas, addition and revision of other topic areas, and explanatory material to justify the design criteria and define tradeoffs associated with the design criteria. The researchers conducted a card sort task on the material and reorganized the topic areas based on the results of the card sort task. A more detailed description of the methods and results of this study is contained within the technical note, along with the full set of guidelines.

Results: Revision of Chapter 9 of the HFDS created notable changes. The search for updated information pertaining to Input Devices revealed a plethora of research. The amount of new information and the way users described how they needed the information led to the realization that the chapter on input devices needed to be separated into two chapters, one on keyboards, and one on non-keyboard interaction devices. The chapter on keyboards remains Chapter 9, while the new chapter on non-keyboard input devices became Chapter 16. Additionally, researchers found that "input devices" was a somewhat outdated term. Since these devices are used more for interacting with a computer system than for input, the term "interaction device" is the appropriate way to refer to these devices. The chapter that emerged from the initial "Input Devices" chapter is now referred to as "Non-Keyboard Interaction Devices". The two separate chapters of Keyboards and Non-Keyboard Interaction Devices will replace the current Chapter 9 of the HFDS. The result of this effort is a technical note describing the background and methods used to create the guidelines, as well as the full set of guidelines. The guidelines are organized to make it easier to find needed information. The information is supported by explanatory paragraphs where necessary. Redundant, obsolete or unverifiable guidelines were removed, and new guidelines replaced outdated material. The old chapter 9 contained 66 guidelines on non-keyboard interaction devices and 44 guidelines on keyboards. The new chapter on non-keyboard interaction devices contains 215 guidelines.

Recent Accomplishments: Both the draft of the non-keyboard interaction device chapter and the keyboards chapter are currently being reviewed.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Human Factors Design Criteria for Design and Procurement of Keyboards

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: Interactions between most systems in the FAA rely heavily on keyboards. Current information on keyboards and keyboard characteristics, their advantages and differences, and appropriate applications is important for the safety and performance of those using the devices and to minimize cost to those programs involved in developing and procuring the keyboards. An updated set of standards and guidelines is needed with an increased scope to cover all relevant keyboard criteria. This document summarizes development of an updated and revised set of keyboard standards and guidelines to assist in creating clarity in the use, design and procurement of keyboards.

Method: Researchers organized the revision in phases. This process included review/verification of information in the current Human Factors Design Standard (HFDS) chapter on input devices, identification of new source material, systematic evaluation of literature, reorganization, addition and revision of certain topic areas, and addition of information to justify the design criteria and define tradeoffs associated with the design criteria. The document and appendix with the design criteria are now being distributed to subject matter experts for review.

In the first phase of this effort, a research team identified guidelines and standards that pertain to keyboard procurement and design. These guidelines and standards were compared against the current HFDS. The information from the HFDS was then updated as needed. Researchers then used references from the guidelines to identify primary sources cited by the reference documents. The primary sources were reviewed and information within the guidelines and standards was verified where possible. During this review, it became evident that the research team needed to obtain additional source materials that were more detailed or more current.

The researchers then conducted a literature review to identify current research related to keyboards. Over 260 potentially relevant sources were identified and reviewed for information relevant to the design or procurement of keyboards. Upon review of each source, researchers weighed relevancy, adequacy and validity of the material before including it in the document. When information in the new source document warranted new or updated standards, a guideline was created or updated. When new source material proved statements in the current document were outdated or invalid, these statements were revised or deleted as necessary. Relevant information from the literature was rewritten into "should" or "shall" statements that could be used in requirements documents.

Results: This effort resulted in creation of two new guideline chapters in the HFDS. The search for current, updated information pertaining to Input Devices resulted in two chapters. The chapter on Keyboards will remain Chapter Nine. The second chapter that emerged from the initial "Input Devices" chapter is now referred to as "Non-Keyboard Interaction Devices", which will become chapter 16 in the HFDS. The previous Chapter Nine had 100 guidelines, 44 of which were about keyboards. The new keyboards chapter has 122 guidelines on keyboards.

Recent Accomplishments:
Drafts of the keyboards chapter and the non-keyboard interaction devices chapter have been sent to subject matter experts for review.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Human Factors Design Standard Update Plan

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: The Human Factors Design Standard (HFDS) is a comprehensive reference document used throughout the FAA to promote good human factors principles in the design and procurement of systems. It is a single, easy-to-use reference source that program managers can use to quickly find answers to human factors design questions. One key to making the HFDS valid is keeping the information current and aligned with the FAA's needs. To accomplish this, the document is updated on the order of one chapter per year. The current effort looked at HFDS information and identified a prioritization for information updates (see image, next page).

Method: The first step involved an analysis of information within the HFDS to identify information that may be outdated. Next, a review of FAA planning documents was conducted to identify systems and equipment that are planned for development or procurement. Researchers performed a high level analysis of the systems to identify human factors areas relevant to that program. These planning documents form a basis of aligning priorities for information with the mission and goals of the FAA.

The third step involved an analysis of past users of the HFDS. This information was obtained from a database of those who have requested CDs or downloaded the HFDS. The database contains information on the country, type of organization, and intended use of the information. Although these fields are voluntary, a full two-thirds of those requesting or downloading the document filled in this information. This database was analyzed to categorize users of the HFDS and determine the current use of the HFDS.

In the final step, information in the database was supplemented by performing more in-depth interviews with a subset of users. Users of the HFDS were identified to determine their needs and priorities through either structured interviews or a survey. Structured interviews were limited to those users who are easily accessible to the researchers.

Results: This is an ongoing effort. To date, researchers have compiled data on users who have downloaded the HFDS or requested the CD. Data are being analyzed to determine user needs. Additionally, researchers have obtained and analyzed FAA planning documents to ensure that the HDFS is aligned with agency goals and objectives. Researchers have also developed a tool for collecting more in-depth information from users. Results of the four steps described above will be integrated into a comprehensive strategic management plan for the HFDS.

Recent Accomplishments: To date, researchers have compiled data on users who have downloaded the HFDS or requested a CD. Additionally, FAA planning documents have been analyzed to ensure that the HDFS is aligned with agency goals and objectives. An on-line tool has been developed for collecting more in depth information from users.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Alarms and Alerts Draft Standard for Technical Operations

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: For many years, the number of systems in the Technical Operations (TO) environment has increased dramatically. As new systems are added, there is often little consideration given to existing systems. This stovepipe approach has led to a proliferation of divergent coding systems for alarms and alerts. The multitude of different colors, sounds, etc., can quickly exceed the ability of users to remember the meaning of each item, potentially leading to errors. As new systems are developed or acquired, program managers and product teams are repeatedly faced with the same decisions on how to effectively code alarms and alerts for TO systems. TO has been moving toward standardization by sponsoring a number of different projects to lay the initial groundwork for development of an TO standard for alarms and alerts. Development of an approved standard has the potential to decrease development time, decrease training, and minimize the potential for errors.

Methodology: The research team is working to identify, obtain, and review research and guidelines material on alarms and alerts. Researchers will determine the extent to which the information is appropriate to the maintainer as the system user. The researchers will identify, obtain, and analyze information on alarms and alerts in current systems. They will develop a meaningful taxonomy for organizational headings, and will use this information to tailor the guidelines and prepare a working draft of the document.

Results: This is an ongoing effort. Materials on alarms and alerts in current systems have been reviewed and documented.

Recent Accomplishments: Researchers continue to identify, obtain and review information on alarms and alerts.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Password Alternatives

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: As security concerns have increased, we have seen new requirements for software password protection. This has led to a proliferation of passwords. In a given office environment, it is not uncommon for a user to have six to ten passwords to remember in order to access various systems. In order to maintain security, users are often forced to change passwords on a regular basis and then relearn new passwords. Users have adapted many different strategies to cope with this memory load. One of the most common strategies is writing the passwords down in case they are forgotten. Unfortunately, this could potentially undermine security of the system. Additionally, if the user forgets a password for a system he/she needs to access in order to address a maintenance alarm, the safety and efficiency of the National Airspace System could be compromised.

Method: This study is examining the advantages and disadvantages of different password and password alternative systems from a human factors perspective. The researchers are collecting information on various password alternatives. They will interview users and program management to determine functional requirements for passwords and password alternatives.

Results: This is an ongoing project. The researchers have written a project plan for data collection.

Recent Accomplishments: The researchers have written a project plan for data collection and are collecting information on various password alternatives.

Primary Investigator: Kenneth Allendoerfer, Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Human Factors of Personal Data Assistants/Hand-Held Computer Devices

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: The purpose of this project is to compile a set of human factors criteria against which personal data assistants (PDAs) and hand-held computer devices can be evaluated. Technical Operations is considering the use of hand-held computers and PDAs as a means of interacting with the National Airspace System Information Management System. There is currently no set of human factors standards creating a set of guidelines. This could lead to programs buying systems that are not suitable for FAA use, which, in turn, could lead to increased potential for errors, lowered performance, or ergonomic complaints by the users. By creating a set of guidelines, programs can make informed decisions on what devices are suitable for the task, saving time and resources.

Method: This set of criteria would provide general recommendations for use. The researchers will obtain current research on the use of these devices, extract relevant information, and provide recommendations based on current research.

Results: This is an ongoing project to create a set of human factors guidelines/criteria to evaluate PDA and hand-held computer systems prior to purchase.

Recent Accomplishments: The researchers have obtained and started reviewing relevant information.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Communication/Coordination between Technical Operations and ATC

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: This study will provide recommendations to improve communication and coordination between Technical Operations (TO) and Air Traffic Control(ATC). TO is responsible for providing operations and maintenance support services for the National Airspace System (NAS). To accomplish this goal, TO Specialists must communicate and coordinate with various entities both within and external to TO. When this communication fails, the NAS infrastructure can be impacted, resulting in service interruption and ultimately equipment outages and delays of aircraft. TO has recently undergone many changes, including a consolidation of operations. The impact of these changes on communication between TO and ATC is unknown. A study conducted last year indicates that communications between the Operations Control Centers (OCCs) and Air Traffic Control is an area in need of improvement. The potential benefit of the current study is improved communication and coordination between TO and ATC. The outcome will be a technical note detailing the results of the study and a briefing to the sponsor describing the study and recommendations.

Methodology: This study is examining communications between the TO and ATC. Researchers will construct a survey instrument and will visit a limited number of TO and ATC field site locations. A researcher will conduct structured interviews with TO and ATC specialists. The data will be analyzed and areas for improvement will be identified.

Results: This is an ongoing project. The researchers have written a project plan for data collection and are currently working on the preparation of Internal Review Board materials.

Recent Accomplishments: The researchers presented the project plan to the sponsor for review. They are conducting a test of questions from the survey with subject matter experts.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Visual Coding of Status for Technical Operations (TO)

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: In order to monitor and control over 30,000 different services and equipment, TO specialists must be provided clear and consistent methods for recognizing status quickly. Without specific guidance on status coding, each new system must come up with a strategy for conveying status information. This can lead to coding that is inconsistent with other systems and often inconsistent with human factors best practices. The purpose of this study is to promote consistency in the coding of status information used for monitoring and control at TO Service Operations Centers.

Method: Researchers conducted a literature search to identify how status is currently coded. As part of the review, previous technical reports, computer based instruction courses, and technical manuals were examined to identify how TO systems currently code status. Data was collected on 97 different items that are coded, and each was defined by system. For each system, researchers identified the primary status screen, what information is conveyed to the user, and what action the user must take to address changes to the primary status screen. Informal interviews were conducted with human factors specialists who work with user teams to gather information on how and why status is coded for different TO systems. These human factors specialists were able to provide insight on where the user teams could have benefited from additional information. The researchers studied the decision processes made by different user teams in relation to the status codes applied. They used this information to create a preferred process for the development of status coding. The process is detailed in a technical note.
The researchers then defined the terms that were used to code status across TO systems. By providing definitions for terms, it is more likely that the items will be used consistently within and across TO systems. Terms that were similar and provide coding recommendations were grouped based on human factors research.

Results: This study resulted in a technical note that defines the various terms used for status-related events in TO, describes the TO work environment, describes current information displays used by TO, and explains how to use the screen to enhance user performance. The document also describes various methods used to code status and provides explicit recommendations based on human factors best practices. If the course of action described in this technical note is successful, it will promote consistency in the coding of status information across systems. This can reduce the time needed to identify and react to a potential problem, minimizing the potential for outages and decreasing the impact of outages that do occur.

Recent Accomplishments: A technical note describing the results of this study is currently under final review. Information from this technical note is already being applied to the FAA.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City, NJ

Web-Based Portal Computer Human Interface Guidelines

FAA Sponsor Organization: Office of Knowledge Management

Purpose and Rationale: The Office of Knowledge Management plans to use a web-based knowledge portal as a tool for knowledge management, content management, and collaboration and application integration. To be successful, the knowledge portal needs to be usable. To ensure that the final product is usable, the Office of Knowledge Management turned to the NAS Human Factors Group for development of a set of computer-human interface guidelines.

Methodology: The authors collected information from various standards and guidelines (including the Human Factors Design Standard), and combined it with examples and lessons learned through human factors experience to form specific guidelines. Guidelines were written in the form of "should" and "shall" statements. Topics covered include page layout, text design, graphic design, and accessibility standards.

Results: This study resulted in a technical note. Although the note was originally written for a specific portal, most of the guidelines can be applied to websites, intranets, and other web-based applications. The note is meant to be a human factors reference tool. When used by an experienced human factors professional, the note can improve the computer-human interface of FAA portals and web-based applications.

Recent Accomplishments: A technical note was published describing the results of this study.

Primary Investigators: Vicki Ahlstrom, Kenneth Allendoerfer, FAA William J. Hughes Technical Center, Atlantic City, NJ

Information Organization for a Web-Based Knowledge Portal Using a Card-Sorting Technique

FAA Sponsor organization: Office of Knowledge Management

Purpose and Rationale: This effort was the second in a series of tasks requested by the Office of Knowledge Management. In order for users to find necessary information within a web-based knowledge portal, the information must be organized in a way that is consistent with user mental models. The Office of Knowledge Management was in the process of creating a portal that would contain an extensive amount of data. To organize the information so that it would be easy to navigate through, they turned to the NAS Human Factors Group.

Methodology: Researchers conducted a card-sorting task to develop an information infrastructure for the future portal. Potential topic areas for the portal were obtained through a combination of items identified by the sponsor as high priority items, current intranet content, and structured interviews with potential portal users. Information items were placed on index cards. Nine participants representing various types of end users sorted the cards into categories and then named the categories. The human factors team grouped similar categories and analyzed the data to come up with scores for strength of belonging to a category and strength of association between items.

Results: The analyses led to development of a taxonomy for the organization of information items within the portal. This study resulted in briefings and a draft report.

Recent Accomplishments: The researchers prepared a draft report documenting the methodology used for this task. The draft report is currently undergoing revisions as part of the internal review process.

Primary Investigators: Vicki Ahlstrom, Kenneth Allendoerfer, FAA William J. Hughes Technical Center, Atlantic City, NJ

Current and Future Issues Related to Air Traffic Control Specialist Selection

FAA Sponsor Organization: AFX

Purpose and Rationale: The Air Traffic Selection and Training (AT-SAT) examination battery is used for entry into the Air Traffic Control Specialist (ATCS) career field. It provides a valid and legally defensible procedure to systematically assess applicants and identify those possessing appropriate knowledge, skills, and abilities to succeed in occupational training and on the job. The current version of AT-SAT is based on a single form for each component sub-test in the battery, leaving the FAA vulnerable to coaching efforts. In addition, some applicants are able to artificially inflate their AT-SAT scores through repeated testing. The Civil Aerospace Medical Institute (CAMI) developed parallel forms of the AT-SAT, and is conducting cooperative research with the Department of Defense to equate the forms and deal with these problems.

Methodology: FY 2004 saw collection of data on the parallel forms from military participants in support of the equating study. The collection and archiving of AT-SAT data continued. Under the Internal Review Board-approved protocol extended this year, students at the FAA Air Traffic Academy are administered AT-SAT (select-in) and experimental personality (select-out) measures. Their progress will be longitudinally tracked and compared with psychological data in addition to the data gathered as part of their medical examination upon entry into the FAA. Work will begin in FY05 to update existing job analyses for the en route, terminal radar approach control and tower options. After completing the job analyses, criterion measures of job performance in the three options will be developed to support a longitudinal validation of AT-SAT.

Results: The military participants are putting forth their best effort and rendering useful data for the equating study. Data collection has been proceeding slower than originally planned due to the impact of the war on terror. A third site, Ft Rucker (Army), AL was added to Pensacola Naval Air Station, FL and Keesler Air Force Base, MS to increase the pool of participants. Data collection from FAA Air Traffic Academy students has also been slow due to the low rate of new hires. When finished, the equated forms of AT-SAT will be directly delivered to the program office responsible for management, oversight, and execution of the controller selection process.

Recent Accomplishment: Simultaneous collecting data at three DoD facilities in the United States that are involved in training military air traffic controllers.

Primary Investigator: Raymond E. King, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Optimizing Human Performance to Reduce ATC Operational Errors

FAA Sponsor Organization: ATO-T and ATO-S

Purpose and Rationale: The overall goal of this research is to develop a better understanding of the relationship between human factors and air traffic system safety. Researchers at the Civil Aerospace Medical Institute are working to understand the role of individual, situational, and work-related factors as they influence operational air traffic controllers' performance and the occurrence of operational errors (OEs). The JANUS technique for evaluating operational errors plays a key role in this process. Findings will be used to develop improved procedures, training, guidelines and other interventions that are based on human factors principles and that enhance performance and improve overall safety.

Methodology: Each OE can be partitioned into one or more critical points and JANUS uses a structured interview process to systematically step through a series of contingent questions which identify causal factors related to the critical point(s). Twenty-nine air traffic facilities covering six FAA Regions volunteered to participate in a *beta test*. From these, JANUS was used to gather data at 12 facilities, through 215 field interviews after 79 OEs occurred. This information was used to evaluate the scientific and operational validity of the technique and to make further enhancements to JANUS. Technical reports summarizing results from the *beta test* and validation activities are in review.

Results: In a series of regional meetings, management and union representatives from the participating ATC facilities were provided feedback on data gathered during the *beta test*. For example, in the national sample, factors related to mental processes associated with perception and vigilance were reported in 41% of the critical points; factors related to traffic and airspace were reported in 49% of the critical points

Recent Accomplishment: Upon seeing the types of data that can result from JANUS interviews, all participants agreed the effort should continue and supported continued participation by their facilities. A web-based tool was identified as a requirement and, as a result, software for an "e-JANUS" application was developed and established on a web server. On-line testing began in September 2004.

Primary Investigator: Julia Pounds, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Longitudinal Assessment of Age and Performance

FAA Sponsor Organization: ATO Workforce Services

Purpose and Rationale: The FY2004 appropriations bill included language directing the FAA to issue regulations for granting waivers to mandatory retirement at age 56 for controllers "having exceptional skills and abilities." Air Traffic Services requested that CAMI: (a) evaluate the scientific basis for mandatory separation at age 56; and, (b) identify factors that distinguish "exceptional" controllers from others. Of primary concern was developing a "firm basis" for retaining, increasing, or repealing mandatory separation of controllers at the specific age of 56., CAMI conducted three studies to assess the relationship of age to controller performance.

Methodology: The first task was to conduct a review of literature relevant to mandatory separation of controllers at age 56. Studies conducted before institution of the mandatory retirement age were reviewed first. These studies were relied upon or cited in Congressional testimony as justification for mandatory retirement. Studies conducted after implementation of mandatory retirement were then reviewed to investigate the relationship of en route operational errors to controller age. Records of en route operational errors were matched with ARTCC staffing data, and the likelihood of involvement in an OE was investigated as a function of controller experience and age using logistic and Poisson regression techniques. The third research task was to conduct an on-line survey of incumbent 1st-level ATC supervisors as to the importance of different factors in distinguishing between "exceptional" and "other" controllers.

Results: The literature review concluded that scientific evidence available in 1971 provided only weak objective support for the rationales behind the "ATCS Age 56 Law." Research since 1971 does *not* support the inherent stress rationale articulated in 1971 for the "ATCS Age 56 Law." However, the available studies also do not offer a "firm foundation" for either supporting or rejecting the mandatory separation of controllers at age 56 in view of the age and performance results. Although cross-sectional in design, the age and performance studies suggest that performance may decline with age and that variability in performance between controllers is likely to increase. The second study matched 3,054 en route OE records from the period FY1997 through FY2003 with ARTCC non-supervisory controller staffing records extracted from the FAA Consolidated Personnel Management Information System (CPMIS) for those years. This resulted in a database consisting of 51,898 records for non-supervisory, en route controllers with and without OEs. Four statistical analyses of increasing sophistication were conducted. Overall, the analyses did not support the hypothesis that the likelihood of involvement in an en route OE increases with age. Rather, it appears that if there is a relationship between age and involvement in an en route OE, it is weak and negative. A total of 659 supervisors participated in the survey. Seven factors distinguishing between "exceptional" and other controllers were identified, including technical skill and reliability/ adaptability as an employee. The results of this survey were used to define criteria for granting waivers.

Recent Accomplishments: This research was accomplished on short notice and on an aggressive timeline to meet the Congressional deadline. Researchers presented several briefings on the results, including to the Administrator and the Associate Administrator for Regulation and Certification.

Primary Investigator: Dana Broach, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Provide Research Support to the Office of Runway Safety

FAA Sponsor Organization: ATO-S

Purpose and Rationale: The Runway Incursion Severity Categorization (RISC) model was developed for the Office of Runway Safety as a tool to assign more objective and reliable ratings of severity to the outcome of runway incursions. The model incorporates expert knowledge in the form of specific incursion scenarios and relevant factors to provide an independent estimate of the severity of an incursion from the expert-group rating system currently in use. The model is being considered as an international standard for rating runway incursion severity.

Methodology: The model was validated using the data reported from 324 runway incursions occurring in FY 2003. A runway incursion rating system database was developed for capturing data from incursion reports, including a natural language processing method for determining incursion scenarios from report narratives. Relevant data included weather, time-of-day, type of aircraft involved, the activity of the aircraft (i.e., takeoff, landing, or taxiing), phase of operations (e.g., final approach), location on the airport (e.g., runway - taxiway intersection), and resulting actions (e.g., crossed the hold short line but did not enter the runway). Two independent raters evaluated each runway incursion report with respect to one of 53 incursion scenarios and three relevant factors. Inter-rater agreement was documented. A severity rating was calculated by the model and compared to the rating assigned by the Office of Runway Safety.

Results: Of the 324 incursion reports evaluated, over 90% were successfully rated by the RISC model, indicating a high degree of inter-rater agreement. The remaining reports were primarily incursions that either involved specific situations that the model was not designed to analyze (e.g., helicopters), or did not contain sufficient information in the report to allow for modeling. On the whole, the model categorized the severity of runway incursions for the FY 2003 into similar numbers of A's, B's, and C's & D's, as were originally rated by the Office of Runway Safety. The model matched the original ratings on incursions rated A, but was less consistent with the original ratings for incursions rated B and C. An analysis of the incursion scenarios revealed that an aircraft crossing, entering, or crossing the hold short line in front of a landing or taking off airplane is the most common type of runway incursion.

Recent Accomplishments: The Office of Runway Safety is working with other civil aviation agencies around the world to develop international runway safety standards. Within this context, the RISC model has been demonstrated in and well received by Europe and Australia. A working version of the model has been developed for use by Air Services Australia. Additionally, the theoretical underpinnings of the model have been presented at international conferences.

Primary Investigator: Kim Cardosi, Volpe National Transportation Systems Center, Cambridge, MA

Statistical Retirement and Attrition Model (SCRAM)

FAA Sponsor Organization: ATO-A

Purpose and Rationale: Most current air traffic control specialists (ATCS) were hired between 1981 and 1996 at an average age of 26 (±3 years) and will soon approach mandatory retirement (age 56). Some may elect to retire at a younger age under "special optional" retirement provisions for controllers, while others may continue working under a waiver. This uncertainty complicates workforce planning and management of the ATCS recruitment and training pipeline. One approach to reduce this uncertainty is to develop a probability-based model of retirements, using eligibility as the starting point and historical separations data. The purpose of this research task at the Civil Aerospace Medical Institute (CAMI) is to develop a prototype statistical tool for estimating future retirement and attrition based on historical separations data for critical occupations in Air Traffic Services (ATS). The tool could be used in ATS human capital planning to estimate future losses from critical occupations.

Methodology: **A**gency-wide historical separations data from FY1996 through FY2002 were obtained from the FAA's system of official personnel data (Consolidated Personnel Management Information System - CPMIS). Next, a method for determining retirement eligibility under Civil Service Retirement System, Federal Employees retirement System, and ATCS "special optional" retirement rules was developed in SPSS software. Historical separations data were analyzed with respect to eligibility, to construct probability tables for (a) controllers, and (b) non-controllers. Finally, the eligibility determination method and probability tables were translated into Visual Basic, and data import, handling, and analysis display routines developed in Visual Basic within the Office 97/Office 2000® environment.

Results: CAMI began the development of a statistical tool for the prediction of retirements based on historical retirements and attritions data in FY1998. An operational prototype that encompassed both civil service and special controller retirement rules was completed and demonstrated in FY2002. Workforce models incorporating recruitment, screening, and testing phases were developed in MS Excel using the @Risk add-in in FY2003. However, further development of SCRAM to incorporate the workforce models and dynamic generation and updating of the underlying probability tables was not completed as planned in FY2003 and FY2004 due to other priority research requested by ATS.

Recent Accomplishment: There were two major accomplishments in this task: (a) use of estimates and forecasts of future retirements developed by CAMI in this research in the ATS Human Capital Plan; and (b) development of a working prototype in MS Visual Basic/Access/Excel with flexibility to handle different retirement rules (e.g., CSRS/FERS and ATCS "special optional" retirement) and import/formatting of CPMIS separations and on-board data.

Primary Investigator: Dana Broach, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Technical Ops Job/Task Analysis for FG-2101 Occupation (AF/JTA-2101)

FAA Sponsor Organization: ATO-R

Purpose and Rationale: Previous job analyses for the Airways Transportation Systems Specialist (ATSS or systems specialist; FG-2101) occupation were incomplete and did not comply with accepted professional and legal standards for job/task analysis in the development and validation of employee selection procedures. In FY1999, Airway Facilities requested that the Civil Aerospace Medical Institute (CAMI) conduct a selection-oriented baseline job/task analysis for the FV-2101 occupation. The results of the analysis would provide a basis for: (a) validating the content of current entry-level selection procedures for the occupation; and (b) identifying changes in the occupation resulting from National Airspace System modernization and technology trends in electronics.

CAMI began a selection-oriented baseline job/task analysis for the FV-2101 (Airway Transportation Systems Specialist) occupation in FY2001, with completion expected in late FY2003. As a consequence of occupational workforce planning conducted by ATS, computer specialists (FV-0334) were identified as a critical occupational group. A baseline analysis of tasks/duties and knowledge, skills, and abilities (KSAs) was initiated in FY2002, but deferred to FY2003 due to funding constraints. Together, these selection-oriented, baseline job/task analyses will be used to construct the prototype Job Analysis Information Database. They will also provide a foundation for the Strategic Job Analysis Methodology for examining future KSA requirements relative to baseline requirements as part of the agency's occupational workforce planning effort.

Methodology: CAMI contracted with North American Business and Management Company to conduct the job/task analysis in FY2001. The analysis was completed in three phrases: (a) a series of subject-matter expert (SME) panels to develop lists of job tasks/duties and KSAs; (b) a structured job analysis survey of all incumbent systems specialists in Airway Facilities based on those lists; and (c) SME panels linking KSAs to clusters of critical and/or important job tasks/duties.

Results: The analysis identified a core set of job tasks/duties across the five systems specialist "specialties" (e.g., communications, navigation, radar, automation, and environmental). The analysis also identified the KSAs that were required to perform the core, critical tasks/duties at the time of hire.

Recent Accomplishment: Identification of the core critical and/or important job tasks/duties across the occupation and identification of the KSAs required at entry. These two elements provide the scientific, and legal foundation for validating content of the current systems specialist entry-level hiring criteria.

Primary Investigator: Dana Broach, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Flight Strip Studies

FAA Sponsor Organization: ATO-T

Purpose and Rationale: One step toward increasing air traffic control traffic handling capacity is to eliminate the use of paper flight strips and substitute less laborious but useful ways to manage flight plans and flight progress. Before developing a new technology that replaces paper flight strips with an electronic form of flight data, it is first necessary to understand how, why, and when controllers use paper strips today. Knowledge of information and operational requirements for flight strips could provide a valuable contribution to decisions about the appropriate method for displaying electronic flight data in towers. The information and operational requirements can be used to identify appropriate Commercial Off-the-Shelf (COTS) electronic flight data displays or develop new electronic flight data displays that can be compared in an experiment.

Methodology: The purpose of the flight strip observation study at tower facilities is to obtain baseline information about how controllers currently use flight strips in the tower environment. Two types of data were collected. First, a subject matter expert (SME) controller observed how tower controllers use flight strips, notepads, and other handwritten documentation while working different positions. The SME recorded each instance of strip marking/usage on a standardized form. Second, data were collected concerning controllers' responses to interview questions. After controllers working in the tower were observed, they were invited to participate in a voluntary interview with questions about how they used strips or other handwritten information. During the interview, the controller completed a short biographical information form. The interviewer then asked the controller questions about why he/she marked or manipulated the strips or other handwritten flight data when observed.

Results: Facilities were chosen to represent different regions, types, levels, and runway configurations. Data collection completed in FY2004 occurred at 10 towers in five metropolitan areas. Preliminary results suggest that mark type and strip movement vary as a function of controller position and airport size. The flight data/clearance delivery (FD/CD) position reported that the primary benefits of marking strips were to assist communication with teammates and reduce workload. Local Control (LC) reported that strip marking supported memory, organization and situation awareness. However, Ground Control endorsed the benefits that were seen by FD/CD and LC.

Recent Accomplishment: Observational and interview data were collected at 10 towers in FY2004. Data collection is complete and data analysis will be completed during the first quarter of FY2005. Results will be briefed to the sponsor. (See image, next page).

Primary Investigator: Carol Manning, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

ATC Information Complexity

FAA Sponsor Organization: ATO-T

Purpose and Rationale: Decision support tools are being developed for air traffic controllers. While the tools are intended to provide decision support and offload tasks from controllers, they may also increase ATC task complexity. Thus, it is necessary to assess the information load that an ATC tool imposes on controllers. The purpose of this project is to

develop objective metrics to measure information complexity associated with ATC displays. The metrics will allow us to use the same methodology with each ATC tool and compare results. The metrics will have a higher value if adding a new tool increases complexity of the information presented. Finally the metrics will support prediction of difficulty in future human-system interface integrations.

Methodology: While it is desirable to derive a number to describe the complexity of a display, it is difficult to achieve such a "single-number measurement" method. Instead, researchers at the Civil Aerospace Medical Institute used parallel approaches to develop multi-dimensional metrics of information complexity and validate the metrics through physical and subjective measurements. The project was started with an extensive literature review on available methods of display evaluation and complexity computation. Based on the literature, factors that contribute to information complexity of ATC tools were identified. Metrics were applied to the ATC tools, such as the proposed Weather Display on the Standard Terminal Automation Replacement System, and results were compared with the baseline display. After the methods are validated, researchers will be able to apply the methods to all current ATC tools and document the evaluation results into an information database.

Results: The literature review and analysis demonstrated that information complexity is mediated by three factors: numeric size, variety and interaction. Complexity factors are evaluated by three distinctive stages of brain information processing: perception, cognition and action. Based on the analysis of ATC displays, nine metrics were identified that measure information complexity: three metrics of perceptual complexity (number of fixation groups, variety of groups, degree of clutter), cognitive complexity (number of functional units, dynamic complexity, relational complexity), and action complexity (amount of keystrokes, mouse movement and eye movement, switch between action modes, action depth of functional units). Each metric can be computed objectively and is independent of any given display. Researchers completed preliminary work in validating the metrics subjectively. One experiment showed that the capacity limit of the functional units (the pieces of information that one can maintain in mental representation) is about 10-12. This result has a number of implications in display design and evaluation. For example, it means that the number of frequently-used menu boxes should be limited to 10-12; the number of types of weather information should be limited to 10-12, etc.

Recent Accomplishment: Researchers developed initial metrics of information complexity based on the ways the human brain works. The values of the metrics directly relate to the cognitive workload imposed by new technologies. Since these metrics are associated with brain functions, capacity limits of controllers (complexity levels) can be identified. By doing so, we are able to answer the sponsors' question "Is this automation tool too complex for controllers?"

Primary Investigator: Jing Xing, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Performance and Objective Workload Evaluation Research (POWER)

FAA Sponsor Organization: ATO-R

Purpose and Rationale: Sensitive and valid task load and work load measures are needed for en route air traffic control (ATC) in order to assess and understand the potential impact new forms of automation and ATC procedures will have on human performance. We also need to ensure that intended benefits for controller productivity have been achieved. A set of numerical measures based on available System Analysis Recording data have been developed to objectively assess controller task load and controller/system performance. These measures are called Performance and Objective Workload Evaluation Research (POWER). One subtask of this project uses POWER measures to examine the relationship between en route sector characteristics and operational errors. The overall purpose of this project is to replicate previous research conducted at one facility by examining relationships between sector characteristics and operational errors (OEs) at multiple facilities while adding to the set of characteristics examined.

Methodology: During FY2004, analyses were conducted using a preliminary dataset to replicate many of the analyses reported in previous research. Most of the analyses compared sector characteristics derived from Adaptation Control Environmental System files (containing map data) with operational error (OE) data obtained from the 7210-3, Final Operational Error/ Deviation Report. The only sector characteristics data available for analysis in FY2004 were "static," or those that do not change with the situation. A parallel effort is being undertaken to identify and develop a methodology for obtaining additional data from the original facility. Most of the supplemental data can be described as "dynamic," that is, those that vary according to the situation. In FY2005, coordination will be effected with additional facilities to allow collection and analysis of their sector characteristics and OE data, along with some of the supplemental data.

Results: Preliminary analysis of the static sector characteristics suggests that cubic volume had a significant negative correlation with the number of OEs while number of shelves was also a significant predictor. Cubic volume was suspected to be highly related to other variables, so another analysis investigated the relationship between a limited set of dynamic traffic characteristics and cubic volume. This analysis revealed that most of the variance in cubic volume could be explained by traffic count and heading changes. This result suggests that dynamic sector characteristics are more valuable than static data in predicting the occurrence of OEs.

Recent Accomplishment: A limited set of data from Indianapolis Center was analyzed in FY2004. To complete the replication study, additional data will be required.

Primary Investigator: Carol Manning, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Develop, Implement, Analyze, Evaluate Strategic Human Capital Metrics

FAA Sponsor Organization: ATO-S

Purpose and Rationale: Organizations must assess critical issues such as employee attitudes and customer satisfaction and relate them through metrics to the achievement of organizational goals. This is necessary to effectively manage the organization and comply with statutory requirements such as the Government Performance and Results Act (GPRA) of 1993. Current research is determining the relationship of factors such as employee attitudes and customer satisfaction to organizational performance as a basis for developing a suite of strategic human capital metrics.

Method: FY2004 research was focused on: (a) completing Employee Attitude Survey (EAS) 2003; (b) planning for the Next-Generation EAS; (c) preparation of customer satisfaction surveys (pilots and Aviation Medical Examiners - AMEs) to evaluate services provided by the Office of Aerospace Medicine (OAM); and, (d) examining the value and effectiveness of services provided by Operations Control Centers (OCCs). EAS 2003 was a census of employees in September 2003. It contained 130 items in three major sections: (1) Indicators of Satisfaction, (2) Management and Work Environment, (3) Respondent Demographics. It also included a comment content item. Approximately 48,900 surveys were mailed to FAA employees. By December 2003, 22,720 valid surveys were returned (46% response rate).

Results: Employees indicated they were somewhat or very satisfied with their jobs (71%). Employees were largely satisfied with compensation (65%). Most were somewhat or very satisfied with their immediate supervisors (61%). Fewer respondents were satisfied with the recognition they received for doing a good job (38%). The majority of respondents indicated that non-supervisory employees and managers are not held accountable. The next EAS will be web-based. However, there are a number of concerns associated with this approach, i.e. access to a computer, and anonymity of results. Planning was initiated to develop two multi-mode (web-based and hard copy) surveys to assess satisfaction with services provided by OAM. One survey will be distributed to a random sample of pilots. The second survey, designed to assess satisfaction of AMEs with services provided by the OAM, will be conducted via the web. Researchers developed three on-line data collection tools to support evaluation of the value and effectiveness of services provided by OCCs. Two instruments are on-line interview guides, to be used by field evaluation staff in one-on-one and group interviews. The other is a broad survey of a representative sample of OCC service users. The survey data will be linked to Maintenance Management System objective data in subsequent analyses.

Recent Accomplishment: Researchers briefed EAS 2003 results to interested stakeholders. In addition, the focus on Organizational Excellence (OE) goals required creation of OE summaries for management and numerous sub-groups. EAS 2003 data was restructured into the appropriate ATO service units. Researchers also participated with the AVR core values work group in planning for an interim survey of the AVR workforce. Other activities were focused around preparations for the conduct of the two customer satisfaction surveys and development of OCC evaluation tools.

Primary Investigators: Carla Hackworth, Dana Broach, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Color and Visual Factors in Advanced ATC Displays

FAA Sponsor Organization: ATO-T

Purpose and Rationale: This research evaluates the impact of color-coding in air traffic systems and seeks to improve the effectiveness of color use. Color is the most effective cue in guiding visual search and segregating information. Inappropriate use of color can reduce controllers' work efficiency and reduce the reliability of information perception. Color-coding may also have an impact on the task performance of color-deficit controllers. The FAA has no formal requirements on color in ATC displays. The FAA does have color vision standards for controller selection based on use of color that occurred in the late 1980's. Given the increased use of color today, it is important to understand the impact of color-coding in ATC systems and evaluate the appropriateness of color use. While previous evaluation efforts have shown various advantages of color-coding, the disadvantages of inappropriate color use have not been adequately addressed.

Methodology: Task analysis was needed to understand how a controller's job performance is affected by color-coding. CAMI researchers conducted facility observation of color use in ATC displays as the first step of task analysis. They also developed models that computed the impact of color deficiencies on ATC tasks such as searching, identification and categorization of information. Next, they applied the model to current ATC displays to assess the effects of color deficiencies. Finally, they documented color use in the primary ATC displays. They also collected a large number of digital pictures of color displays from facilities. In FY 2005, they will build a database of images to prepare displays for use in future experiments.

Results: Demographics of the controller workforce were analyzed to identify those having color vision deficiency. Regional flight surgeons confirmed the current figures. Results indicated that about 124 controllers have varying degrees of color vision deficiency. Observations of nine ATC facilities indicated that colors are extensively used in ATC displays, and nearly all the basic colors are being used to encode both critical and non-critical information. Researchers conducted a preliminary assessment of the potential impact of a color vision deficiency on controllers' use of the various ATC displays. Results suggest that in most instances, color is used as a redundant cue. However, the presence of a color vision-deficiency, depending on the type and degree, may result in a controller spending additional time identifying and reading the necessary information. Through collaboration with researchers from the William J. Hughes Technical Center, they also documented color use in many ATC displays and identified a number of color factors that could influence task performance.

Recent Accomplishment: The study illustrates significant changes in the use of color in displays recently introduced in the ATC system. In the en route environment, new displays have replaced the use of paper flight progress strips (which were a factor in development of the existing practical test used to screen applicants' color vision). These factors lend support to the requirement for a thorough analysis of color in advanced displays. The results will provide a foundation for determining the adequacy of existing color vision standards and the practical tests used to screen applicant's color vision. Color use across ATC displays was documented and color factors that have some potential to influence ATC task performance were analyzed. The results will help develop future baselines for color use in advanced displays. The results are providing support to the ATEAM's effort to set up a color palette for terminal displays.

Primary Investigator: Jing Xing, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

ATC Intra-Team Communication and Coordinated Decision-Making

FAA Sponsor Organization: ATO-S

Purpose and Rationale: The purpose of this research is to identify the cognitive processes associated with a break-down in coordination/communication between local and ground control. Reducing runway incursions remains a top priority of the FAA due in large part to a four-year trend (1997- 2000) of continual increases in the number of reported incidents. In the latest review of the literature, researchers noted that the lack of information or incomplete coordination was a causal factor associated with runway incursions 18% - 44% of the time. In the report, they defined coordination as "a failure of one controller to relay needed information to another controller, or a failure to obtain approval for a specific operation (such as a failure to coordinate a runway crossing)". Since runway incursion report forms do not provide enough detail about the lack of coordination between local and ground control, there is a need to examine narrative reports to identify underlying human factor causes associated with problematic intra-team coordination/communication.

Method: Eighty-nine narrative descriptions of runway incursions involving a break-down in coordination/communication between local and ground control were extracted from the FAA Operational Error (OE) database for the years 2000-2003. A subject matter specialist in cognitive psychology analyzed the narratives for indicators of cognitive processes that may have contributed to the miscoordination/ miscommunication. The data were analyzed separately for ground and local control.

Results: Seven cognitive processes were identified as potential causes of miscoordination/ miscommunication: (1) goal interference, (2) similarity confusion, (3) experience interference, (4) attentional blink, (5) tunnel vision, (6) memory consolidation, and (7) memory overload. Preliminary results suggest that the three most prevalent cognitive processes that interfere with ground and local coordination/control communication are (1) memory overload, in which memory capacity is exceeded at a given point in time, (2) tunnel vision associated with a controller focusing on one aspect of the visual field and thus not noticing what is occurring elsewhere, and (3) memory consolidation, in which a person's attention is directed elsewhere prior to information being stored. There were no statistical differences observed between ground and local control.

Recent Accomplishment. Following a briefing of the results, the project sponsor requested that the research be expanded to include a similar analysis of OEs associated with a break-down in coordination/communication between R-side and D-side controllers in air route traffic control centers. If similar results are observed, then the sponsor requested that a FY 2005 brochure be published to provide controllers with insights on how to mitigate the risks associated with the seven cognitive processes.

Primary Investigator: Larry Bailey, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Optimizing Human Performance to Reduce Runway Incursions

FAA Sponsor Organization: ATO-T, ATO-S

Purpose and Rationale: As air traffic at our nation's airports increases, the runways and taxiways become congested with aircraft and airport vehicles. This research will help us understand individual, situational, and work-related factors that influence the operational performance of controllers, pilots and ground operations personnel, ultimately leading to runway incursions. The findings will be used to develop improved procedures, training, and guidelines based on human factors principles to enhance performance and improve overall surface safety.

Methodology: Three studies related to ground operations were conducted. Study one examined narrative summaries from vehicle and pedestrian deviation (VPD) reports to identify human factors that contributed to the incidents. Next, subject matter experts in airport operations at Will Rogers World Airport in Oklahoma City were recruited and JANUS was adapted for ground operations. Study three used the taxonomy developed in Study two to re-analyze information contained in the VPD narratives. Reporting forms used for pilot deviations were examined. A sensitivity analysis was conducted comparing these forms and the JANUS taxonomy. Items unique to each reporting instrument and those in common across instruments were identified.

Results: Examination of 277 VPD narratives showed that approximately 74% were deviations involving movement unauthorized by ATC and approximately 26% were deviations after movement was authorized by ATC. All pedestrian movements were unauthorized by ATC. Vehicle movements were both authorized and unauthorized by ATC. The human error information about vehicle operators was examined. Of the cases with sufficient information about those who received authorization from ATC, six human error categories emerged: hear-back/read-back errors; acknowledgment by operator but incorrect vehicle action; operator ignored ATC instructions; air traffic control inferred operator understanding; operator provided ATC with incorrect information; and operator in contact with ATC not relaying directions to those being supervised. Of those who did not receive authorization from ATC, three human error categories emerged from the narratives: lack of radio contact; failure to observe standard operating procedures; and, vehicle operator initiated movement in anticipation of receiving ATC approval. Results showed where improvements in reporting of vehicle and pedestrian deviations could be made. The comparison of pilot deviation reporting forms with JANUS items showed that each had unique elements, and many items focused on describing the situation at the time. Items on each form on similar topics (e.g., weather at the time of the incident) were posed in a variety of ways making item comparisons difficult. A technical report was prepared discussing these similarities and differences between the reports and how the reports could be combined.

Recent Accomplishment: Analysis of available data on vehicle/pedestrian and pilot deviations revealed a need for improved reporting forms and more detail about factors associated with the occurrence of these events (for example, procedures for authorized versus unauthorized access to airport surfaces). Current reporting forms for these incidents can be improved. A reporting tool is required that identifies causal factors which can be addressed at both the individual operator/pilot level and system level. A technical report discussing these issues is under review.

Primary Investigator: Julia Pounds, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

NATPRO

Sponsor Organization: ATO-T

Purpose and Rationale: The National Air Traffic Professionalism (NATPRO) project is an example of how information identified by operational error (OE) analysis can be turned into a training strategy for skill enhancement. Rather than relying solely on knowledge-based training, this approach integrates the concept of "performance coaching," using an awareness seminar coupled with a practicum. We believe that this program will have positive effects on both the individual controller and on system safety metrics such as OEs because it targets human factors, the mechanism that translates the potential for error into error. In FY 2004, results of a limited deployment at Miami ARTCC were analyzed, and materials for the seminar and practicum were refined based on lessons learned from the study. These materials were used to support deployment of the program to all other ARTCCs prior to FY 2005.

Methodology: The test data from Miami ARTCC were analyzed, software programs were debugged, and a central server site for continuous data collection and feedback was consolidated. The coaching materials were further developed and prepared for distribution to the coaches. The practicum software program was installed in CBI laboratories at every ARTCC.

Results: Results of the Miami deployment showed that the NATPRO program increased ATC participants' knowledge about targeted skills, and participants' evaluation of the training was positive. Results also demonstrated that the change in controllers' performance compared favorably to results from similar skill enhancement programs for controllers and other high performance professionals.

Recent Accomplishment: In FY 2004, results of the limited deployment at Miami ARTCC were analyzed and materials for the seminar and practicum were refined based on lessons learned from Miami. These materials were used to support deployment of the program to all other ARTCCs so that by the end of FY 2004, the practicum software was installed in all ARTCCs. Additionally, performance coaches from every ARTCC were trained and are conducting seminars at their facilities.

Primary Investigator: Julia Pounds, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Shiftwork Countermeasures Assessment

FAA Sponsor Organization: ATO-W (Technical Operations)

Purpose and Rationale: This research extends understanding of the role of individual, situational, and work-related factors that influence operational performance. The objectives are: (1) document the role of shiftwork, fatigue, workload, and environmental stressors as they impact Air Traffic Control (ATC) and Tech Ops (TO) workforce performance; and, (2) develop and evaluate countermeasures to assess their effectiveness in enhancing performance and safety. With success of a practical educational tutorial regarding shiftwork and fatigue for ATC, a modification for AF was proposed. In addition, the FAA Flight Inspection Office tests navigational aids for calibration tolerances. Crews often conduct flights during odd hours, in high traffic, and following rapid trans-meridian relocation. Validation of a fatigue management scheduling-tool was proposed to improve work schedules, rest routines, and reduce fatigue.

Methodology: Modification of the ATC Shiftwork Coping Strategies CD incorporates specific AF workforce information on shift scheduling practices and working issues. Focused educational modules include: shiftwork, circadian rhythms, sleep, schedule-related disruptions, and coping strategies. A DoD developed fatigue and performance model (Sleep, Activity, Fatigue, and Task Effectiveness -SAFTEÔ) is the basis for an MS Windows-based Fatigue Avoidance Scheduling Tool (FASTÔ) that assists in designing aviation/flight missions to mitigate degrading effects of fatigue and jet lag. Validation efforts continue to adapt the tools for application with the FAA Flight Inspection Office (FIO). FASTÔ will be introduced to operational personnel for validation with FAA mission-specific data acquisition. Ultimately the tool will be tailored to assist in the design of inspection flight schedules that minimize "jet-lag" disruptions and fatigue.

Results: A contract was awarded for modification of the Shiftwork Coping Strategies CD. A TO workgroup provided input, and distribution is scheduled for fall, 2004. AVN management received a briefing on a proposed study to gather sleep, fatigue, and performance data from FIO flight crew members. The data will support validation of the FASTÔ scheduling tool for international and domestic inspection missions. Management asked that arrangements be made to brief flight crew personnel. The Civil Aerospace Medical Institute Institutional Review Board (IRB) approved an integrated research protocol to acquire operational environment-linked subjective and objective measures of activity, sleep, fatigue, and task performance from aircrew and airborne electronic technicians. Data collection will occur during routine inspection operations to quantify and compare the FAST™ model predictions and validate certain aspects of the SAFTE™ model. Data collection began in September, 2004.

Recent Accomplishment: An AF work group agreed on proposed revisions of the CD. A contract was awarded for the CD modification effort. AVN management coordinated on introductory briefings to operational personnel. A research protocol was approved by the IRB. Researchers participated in the first meeting of the DOT and other agency "Shiftwork Management Accreditation and Certification Working Group" as well as a NAS Technical Operations Support Office kick-off meeting of the "Human Factors Resource Team."

Primary Investigator: Thomas E. Nesthus, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

ATC Operational Error Severity Index Research

FAA Sponsor Organization: ATO-T and ATO-S

Purpose and Rationale: There are two thrusts to this research: (1) Conduct a scientific evaluation of the ATC Operational Error Severity Index (OESI); and (2) Identify the performance attributes of certified professional controllers (CPC) that Quality Assurance Specialists (QASs) perceive to be most closely associated with whether an OE is classified as "controlled" vs. "uncontrolled." OESI employs a subjective assessment of whether the CPC was aware that an OE was occurring at the time of minimal separation. A more objective measure is needed to insure consistency of judgment and training of QASs.

Method (Thrust 1): OESI consists of five components: (1) vertical separation, (2) horizontal separation, (3) closure rate, (4) flight path, and (5) controller awareness at the time the OE occurred. Statistical analyses were conducted on the FAA OE database for April 2001 through May 2003. Descriptive statistics were used to assess the distribution of OEs across the five components. Aircraft safety margin was examined by analyzing the distribution of OEs based on the percentage of required horizontal and vertical airspace available at the time of closest aircraft proximity. Correlations between each rating category comprising the SI and the SI scores were computed to understand relationships between the ratings and the overall SI score. Discriminant analyses were conducted to explore bias between High Moderate and High Severity OEs.

Results (Thrust 1): There was considerable variability in vertical separation, mean of 621 ft. and SD of 484.49. In contrast, the horizontal separation had a SD of 1.34 around the mean of 2.932 miles. Nearly one-half of the OEs involved a Diverging/Non-Intersecting flight path. OEs were fairly evenly distributed across the closure rate categories used for GA and commercial aviation. Approximately 75% of controllers were not aware that an OE was developing before it occurred. In the en route environment, the vast majority of OEs occurred within 60% or more of the required horizontal separation. Only a small number of OEs, from 0.7% (4/571) for En Route 2,000 ft to 10.5% (71/671) for TE-Single-Site separation, involved 30% or less of prescribed horizontal and vertical separation**.** Correlations between horizontal separation and the other OESI measures were consistently higher than those between those measures and vertical separation. This suggested that horizontal separation plays a more prominent role in predicting the OESI score than does vertical separation. The results revealed there was little rater bias.

Method (Thrust 2): Research is being conducted on observable behaviors that provide an indication that a controller was not aware that he/she was going to have an OE. Data collection involves conducting cognitive interviews of QAS instructors to examine characteristics they use to determine if a CPC was in control of the aircraft at the time of the OE. Instructors will view a set of OE playbacks and transcriptions of pilot/controller exchanges. Next, they will provide impressions of the severity of the type of OE being reviewed, list attributes used to make judgments of ATC control, and describe the complexity of the problem the CPC had to resolve.

Results (Thrust 2): The cognitive interviews will begin in the fall, 2004.

Recent Accomplishments. Researchers completed coordination and arrangements for participation of QAS instructors in the project.

Primary Investigator: Larry Bailey, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Develop a Baseline Operational Communications Database to Describe Current Operational Voice Communications between Pilots and Controllers, and System Performance

FAA Sponsor Organization: ATO-W (Technical Operations)

Purpose and Rationale: Data on the current operational communications system are needed to establish a baseline against which the NEXCOM system performance can be compared. The existing data on controller-pilot operational communications were collected between 8-10 years ago, and may not constitute a valid basis for comparison with, or extrapolation to, the expected NEXCOM operating environment in 2010. Data to support analyses of communications are limited in scope or outdated. For example, there is a lack of baseline data for blocked pilot-controller transmissions against which to assess the performance of new enhancements. Research is needed to identify and fill the gaps in communications data that would contribute to future communications research and studies.

Methodology: This task analyzes copies of time-stamped digital-audio-tapes (DAT) containing controller-pilot voice communications provided by staff personnel from five FAA-operated terminal radar approach control (TRACON) facilities. The recordings were made during peak traffic periods representative of the most communications-intensive operations. Verbatim transcripts and analogue wave files were made and are being used to develop baseline descriptive statistics. This information will characterize current air traffic control communication task performance and describe the timing parameters that characterize current operational voice communication exchanges between pilots and certified professional controllers.

Results: Research support staff transcribed verbatim communications. There are 31,850 lines of data (18,261 approach, 13,589 departure) in the master database representing 50 hours of time on position (25 hr. approach, 25 hr, departure). The complete database will be used to conduct a content analysis of pilot/controller voice communications. In addition, 10 hrs of communications (one hr approach, one hr departure from each TRACON facility) representing the most communication intensive periods (four - 15-minute segments) were selected for a detailed analysis of the timing parameters of the voice communications system.

Recent Accomplishment: Final changes to the *Communication Data Dictionary and Procedures Manual* are being made. It contains all dependent variables, their levels (as appropriate), operational definitions and descriptions on how to encode them using controller and pilot transmissions as examples. Encoding of content and duration measures for each pilot and controller transmission is also nearing completion. Duration measures included set-up delay, voice-streaming time, pause duration following voice offset, message propagation, frequency occupancy time, and lag time. These data will provide baseline measures of controller and pilot communication activity and will be extremely useful for evaluating the effects of changes in equipment and procedures.

Primary Investigator: O. Veronika Prinzo, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Human Factors in Future Oceanic Systems Architectures

FAA Sponsor Organization: Air Traffic Planning and Procedures Program

Purpose and Rationale: Current Oceanic ATC has the potential to enhance performance through application of improvements in communication, navigation, and surveillance (CNS). Integration of these systems introduces human factors issues identified through field studies at Oceanic ATC facilities. First is the impact of mixed communication and surveillance equipment which requires a controller to integrate asynchronous information and apply different equipment-based separation standards. This may increase controller workload and bias the controller against the equipment, negating the benefits of equipping. The second issue is a mismatch between time and space separation restrictions and information support, requiring controllers to resolve temporal/spatial mismatches. These issues are being examined at MIT, the FAA, and in Iceland.

Methodology: The issues described above were identified through human-centered systems analysis based on the results of field studies at New York, Oakland, Reykjavik, and Shanwick Centers. The results were also used to develop a thorough understanding of the cognitive and system risks with each of the issues. Two part-task experiments studied the issues further: (1) *Mixed Equipage Experiment:* One set of the experiments looked at the effects of varying surveillance frequency and separation minima between aircraft within the same airspace; (2) *Time-Space Projection Experiment:* This experiment investigated techniques to correlate time/space projection using constant aircraft velocity as a method to linearly transform between temporal and spatial domains.

Results: *Mixed Equipage Experiment*: There are issues with controller workload, and controllers choose to maneuver equipped aircraft when in conflict with unequipped aircraft. These limitations will become a barrier to transition by negating the benefits of equipping. Airspace segregation and controller display support are essential to the evolution of Oceanic ATC. Equipment dependent airspace segregation is needed to provide tightly packed, optimal routes to aircraft. Also, current equipment indicators on flight strips is inadequate for future requirements and varies across facilities. There is a need for display clarifications in future Oceanic ATC systems. *Time-Space Projection Experiment*: Controllers correlated time and space projection when a repeatable set of aircraft dynamics was present. Controllers projecting air traffic that proceeded along standardized speed profiles (either both decelerating at the same rate or both maintaining a constant speed) projected separation more accurately and more quickly than aircraft proceeding along two different speed profiles. Controllers projecting separation of two aircraft decelerating at the same rate were able to project aircraft as quickly and as accurately as two aircraft proceeding at constant speeds. One explanation is that there is a simple linear projection heuristic that can be established for relative separation projection in the constant speed and both decelerating cases. In the mixed profile cases, no simple heuristic could be established due to the nonlinear relative separation change. Results suggest flexibility can be introduced when new airspeed descent profiles are considered, but controller projection should be supported through a standardized airspeed profile across aircraft.

Recent Accomplishment: Paper outlining Oceanic ATC issues will be published in the Proceedings of the Human-Computer Interaction for Aeronautics International Conference 2004. Preliminary functional requirements for prototype future oceanic system have been developed.

Primary Investigator: John Hansman, Massachusetts Institute of Technology, Cambridge, MA

Human Factors Challenges in Traffic Flow Management Integration

FAA Sponsor Organization: ATO-R Traffic Flow Management Development

Purpose and Rationale: This study represents the third in a series of three high-level investigations that address human factors associated with the integration of FAA air traffic management systems. The first investigation dealt with Terminal Radar Control (TRACON) systems, and the second examined Air Route Traffic Control Center (ARTCC) systems. This third investigation is directed toward the examination of human factors issues in the integration of traffic flow management (TFM) systems. The TFM development team would like to use the results of this effort in requirements for the TFM-Modernization contract. The contract will build an open system to facilitate integration. While the primary legacy system (Enhanced Traffic Management System-ETMS) has continually incorporated and integrated new and improved functionality, additional tools have been proposed and demonstrated. Potential issues with the integration of those tools with ETMS will be described.

Methodology: The research objectives are to describe human factors challenges that may confront future TFM development as efforts are directed toward further integration. To achieve this objective, evidence gathered from interviews with researchers who are developing new TFM tools is being reviewed along with documents describing concepts of use and operations, and findings from operational evaluations. Information on new functionality will be evaluated in light of TFM information needs as determined through over-the-shoulder observations and interviews with traffic management coordinators (TMCs) and specialists working in towers, TRACONs, ARTCCs, and at the Air Traffic Control System Command Center. Researchers are recording instances of similar functionality in different tools and are exploring opportunities for workload reduction through further integration of communications and logging.

Results: Initial conclusions based on literature review, discussion with researchers developing new tools, and observations and interviews conducted at seven facilities include the following: (1) the principle of return on investment needs to be heeded. Systems that require effort from one facility to benefit another facility meet with resistance. A possible solution is to reduce the effort involved; (2) tools that are not integrated into the workstation and require leaving the workstation to use are used infrequently; (3) there are many opportunities to reduce communications workload through further integration.

Recent Accomplishment: Researchers have observed and discussed the use of TFM systems at seven facilities and plan to visit three others. Each was selected because it was involved in the evaluation of prototype tools. The visits provided an opportunity to examine the systems that were in use and to discuss their use with traffic management coordinators and specialists. They were also able to observe inefficiencies that could be improved through further system integration.

Primary Investigator: Eric Nadler, Alan Yost, Volpe National Transportation Systems Center, Cambridge, MA

Human Factors Issues in the Support of Collaborative Decision Making in the NAS (National Airspace System)

Sponsor Organization: ATO-R

Purpose and Rationale: This project has three goals. The first is to provide design input for a suite of Reroute Advisory Tools. Specifically, this focused on the design of the Create Reroute Tool (in the Traffic Situation Display) to be used by ATCSCC specialists in creating reroute advisories, and the design of the Reroute Advisory Display Tool (in the Common Constraint Situation Display or CCSD) to be used by FAA traffic managers and NAS users (dispatchers). The second goal is to provide input on redesign of the display for the FAA's Collaborative Convective Forecast Product (CCFP). The third goal is to complete a needs assessment focusing on ways to improve the routing of flights to deal with weather and traffic constraints. Completion of these goals will help to significantly improve handling of NAS constraints, while reducing workload and better accommodating the priorities and constraints of NAS users.

Methodology: Four approaches were used: (1) Structured interviews and focus groups with FAA and airline staff to conduct needs assessments; (2) Post Operations Evaluation Tool analyses to provide objective data about scenarios that arise in the NAS and that offer insights into problematic or successful responses to weather and traffic constraints; (3) analytical evaluations (heuristic analyses) of proposed tool designs to assess potential usefulness and usability; and, (4) the design and implementation of prototype tools to explore and communicate alternative designs to meet identified needs. As described above, these methods were applied to identify opportunities for improving communication about traffic flow management plans (via a new process for disseminating reroute advisories), to evaluate alternative designs for the CCFP, and to identify opportunities for further improvements in collaborative routing.

Results: Researchers provided significant input to the design of the suite of reroute advisory tools. These tools became operational in May, 2004, and were used extensively over the summer. Similarly, input regarding the design of the CCFP was well received by the FAA advisory group responsible for making the final design decisions. The result was agreement on a new design for displaying weather forecasts using the CCFP, which will be implemented in Spring, 2005. With regard to the third goal (conducting a needs assessment to identify additional opportunities for improving collaborative routing), 11 focus areas were identified. Several, such as the design of tools and procedures to support a new type of ATCSCC advisory (the dynamic reroute request advisory), have been made a priority for development and operational use in 2005.

Recent Accomplishment: Research has provided both strategic and detailed input into the design of new tools and procedures for the creation and dissemination of reroute advisories. The research team originated a proposed new format for reroute advisories and identified necessary tools. They worked with ATCSCC, ARTCC, Volpe, FAA Tech Center, MITRE, and airline staff to make this proposal a reality. Based on experience this summer, the head of the Severe Weather Unit for ATCSCC indicated: "About 90% of the reroute advisories are now created using the Create Reroute Tool, sending out advisories and flight lists via the CCSD to the users. The new tools are very easy to use and have been well accepted by Command Center specialists and the NAS users."

Primary Investigators: Philip J. Smith, Charles Billings, Ohio State University, Columbus, OH

Producing Results – Human Factors Engineering

Program Manager Glen Hewitt directs activities focused on the application and integration of human factors engineering in systems acquisitions related to the definition, procurement, design, development, testing and implementation of diverse systems within the FAA and National Airspace System. Activities are conducted that are associated with building a human factors engineering program within the FAA and its systems engineering community. The program addresses the application of human factors engineering during mission and requirements analysis and development; investment analysis; product analysis, design, development and testing; source selection preparation and evaluation; and post-deployment data collection and analysis.

The objectives associated with this program area are designed to ensure that the incorporation of human factors engineering is explicit, timely, systematic, comprehensive, efficient, and effective. Efforts relate to identifying and defining system-specific human factors requirements, assessing human factors risks, providing technical solutions to mitigate risks, advising on policy decisions related to human factors engineering, conducting human factors training, acquiring and supporting human factors tools and technologies, and implementing human factors plans. Technical support to system acquisition programs encompasses areas of study related to human-computer interface, staffing and training, workload, procedures, documentation, communications, and other salient human-system interface issues.

Human Factors
Engineering

Human Factors Workbench

FAA Sponsor Organization: ATO-P R&D

Purpose and Rationale: The Human Factors Workbench capitalizes on related efforts to assemble useful information for human factors specialists and managers in the human factors community. The Workbench presents a comprehensive treatment of the most needed information for human factors practitioners. It ties valuable information together under four components: (1) human factors process descriptions offered in 10 updated chapters of the Human Factors Acquisition Job Aid as the basis for outlining essential processes and activities conducted during the acquisition management system lifecycle; (2) a taxonomy and product description for more than 100 human factors tools; (3) basic training about human factors using the 10 modules of the newly created web-based Human Factors Awareness Course/Tool; and, (4) hundreds of publications, studies, and other papers assembled into a relational database that can be easily explored with embedded search tools.

Methodology: The Human Factors Workbench is web-based, providing FAA employees, system acquisition developers, and other associated individuals easy access to human factors information to support aviation-related human factors activities. It provides a compendium of essential information for practicing human factors in an easily accessible framework on the web.

Results/Recent Accomplishment: Creation of the web-based Human Factors Workbench has increased availability and accessibility of critical information. It provides needed information to the human factors community, promotes the sharing of knowledge about human factors best practices, and helps acquisition professionals, the FAA workforce, and associated participants accomplish FAA objectives for the National Airspace System.
The Human Factors Workbench also promotes use of important information related to solving human-system performance challenges in the aviation community.

Primary Investigators: Dino Piccione, Glen Hewitt, ATOP-R&D, Washington, DC

Tower Siting/Visibility

FAA Sponsor Organization: ATO-T Program Operations

Purpose and Rationale: Human factors expertise was provided in the revision and update of FAA Order 6480.4, *Airport Traffic Control Tower Siting Criteria*. This order was originally published in 1972. Capitalizing on recent research and assistance rendered for the siting of the Deer Valley, AZ airport traffic control tower, recommendations were provided on concepts and analysis methods to address object obscuration, object discrimination, line-of-sight angle of incidence (look-down angle), two-point lateral discrimination, and tower cab design human factors considerations. Graphics, formulae, and examples were provided to clarify the use of human factors concepts.

Methodology: In the precursor endeavor, a team of researchers from the U.S. Army Research Laboratory, the University of Nevada-Reno, and the FAA (ATOP-R&D; AWP-510) conducted tests to quantify what improvement can be gained by increasing the Deer Valley airport traffic control tower (DVT) height from 110′ to 130′ or 150′. Specific analyses included: (1) what improvement in visibility (detection, recognition, identification) can be gained by increasing the DVT tower height, and (2) what improvement in discriminating two spatially disparate points can be gained by increasing the DVT tower height. These analyses provided a methodological basis for establishing criteria for visibility analyses that would improve tower height and siting decisions.

Results/Recent Accomplishment: Follow-on investigations of tower siting procedures revealed that additional visibility analyses and criteria such as those for observer line-of-sight angle of incidence (look-down angle) could enhance the objectivity of tower acquisition decisions. Procedures for conducting the applicable analyses were refined while human factors specialists conducted research to define appropriate decision criteria. The resulting analysis methods and criteria were drafted as recommendations to the airport traffic control tower siting order. In addition to the many factors that determine tower height and location, the recommended visibility analyses provide quantitative data to establish airport traffic control tower requirements and to assist in engineering and acquisition decisions using performance-based information about human capabilities.

Primary Investigator: William "Kip" Krebs, Glen Hewitt, ATOP-R&D, Washington, DC

Human Factors Acquisition Reviews

FAA Sponsor Organization: ATO-P R&D

Purpose and Rationale: For FY04, in addition to and in concert with the changes made in the FY04-08 Flight Plan, human factors considerations were integrated into several agency goals and objectives. Flight Plan ARA Safety Goal Objective 8 (Activity 9) entailed conducting Human Factors Reviews between representatives of the Human Factors Research and Engineering Division (HF R&E, ATO-P) and the service area Integrated Product Teams.

Methodology: Human Factors Reviews provide a collaborative process for achieving agency objectives for Human Factors Research and Engineering. The process is described in the Human Factors Review Process. HF R&E works collaboratively with the Service Areas and other human factors practitioners to ensure program managers and team leaders have the best information on human factors issues that may impact their programs by:

- Providing information on risks identified (or likely to be identified)
- Offering recommendations on potential means to mitigate HF risks
- Identifying and resolving obstacles to accomplish human factors research and engineering
- Receiving feedback and/or requests for assistance

Results/Recent Accomplishment: Several successful annual reviews were scheduled by the Service Area's designated human factors practitioner and conducted with the HFRED. Emphasis during FY04 was placed upon four areas (infrastructure, risk assessment and mitigation, cross-cutting needs, and lessons learned). As a result of the reviews, 17 ATO recommendations were identified for FY05 and beyond. Major findings and recommendations include those in the following areas:

a. **Strategy:** Creation of a new strategy for incorporating human factors in system acquisitions
b. **Staffing:** Development of a revised Human Capital Management Plan for Human Factors to support ATO needs for availability and organizational coordination of resources
c. **Policy:** Revision of human factors policy to clarify roles and responsibilities, and improve integration
d. **Safety Management System:** Establish human factors guidance for support of the ATO Safety Management System
e. **Measures and Metrics:** Use of human-system performance measures, and quantification of human factors and human-system reliability in service area analyses, program requirements, acquisition baselines, system testing, and post-deployment assessments
f. **Source Selection Criteria:** Use of human-system integration criteria in Section M of Source Selection (proposed contract) Evaluations

Primary Investigator: Glen Hewitt, ATOP-R&D, Washington, DC

Human Factors Engineering

FAA Sponsor Organization: ATO-P R&D

Purpose and Rationale: As part of the FAA's effort to integrate human factors engineering into all systems and applications, emphasis continued to be directed toward two elements: (1) institutionalizing policy, processes, and best practices; acquiring technical tools, capabilities, and techniques, and conducting human factors training and professional development; and, (2) conducting risk assessment and mitigation activities across systems and applications to: (a) assess compliance with human factors best practices; (b) monitor and revise human factors infrastructure requirements; (c) ensure human factors impacts and risks continue to be identified, documented, and resolved; (d) ensure resource requirements and implementation plans are established to resolve outstanding issues; and, (e) ensure activities are conducted to apply human factors engineering principles.

Methodology: A broad range of activities are undertaken in pursue of the human factors engineering integration objectives. This program establishes an approach for research and technical support of acquisition systems/programs, domains, and other acquisition activities and applications and monitors the achievement of program objectives. Objectives of the approach include:

- Assist in achieving ATO performance objectives
- Provide a mechanism to maintain and document changes and progress in the human factors program
- Execute a concept that integrates process improvement, acquisition program reviews, HF acquisition professional development and training, and other initiatives and developments
- Plan the appropriate expenditure of limited resources supporting this effort

Under the Acquisition Management System, the Integrated Requirements Teams (IRTs), Investment Analysis Teams (IATs), and Integrated Product Teams (IPTs) are empowered, cross-functional teams that have the responsibility for participating in the delivery of a product or service that meets the needs of their customer. The integration of human factors into these teams and the application of human factors to acquisition programs helps ensure that the system design is human-centered, meets program goals and objectives, reduces risk, lowers life cycle costs, and achieves a higher probability of program success. Human factors research and support to IRT/IAT/IPTs ensures the most effective use of human capabilities and minimizes the effects of human limitations and errors on the overall performance of the system. The degree of human factors support required varies by program and considers the complexity of the system, the acquisition strategy, the phase of development, interaction and integration with other systems, and the level and type of human involvement.

The concept of coordinated and decentralized execution of a human factors program consists of two primary elements: 1) a centralized element of a small number of resources to help direct, manage, coordinate, support, and integrate disparate research and engineering acquisition human factors activities, and 2) a decentralized element collocated with the domains and environments to coordinate and integrate human factors research and engineering activities within and across the domains/environments. The human factors "decentralized" role is executed by human factors coordinators (HFC) collocated in appropriate quantities within the business lines and IRT/IAT/IPTs to ensure that adequate human factors support is rendered. In acquisitions, the HFC's major responsibilities include participating in the development of

integrated requirements, supporting investment analysis of alternatives, assisting in SIR preparation or market surveys, serving on source selection panels, preparing human performance test and evaluation criteria, preparing data collection and analysis plans, participating in post contract award activities (attending CDRs, PDRs), etc. This approach accommodates considerations of critical mass, the exchange of discipline unique information, the sharing of lessons learned, the efficient use of resources, and the relation between research and applications.

Overall program review of the institutionalization of human factors for acquisition support is addressed using measures such as the major functions and attributes below.

FUNCTIONS	ATTRIBUTES
Direct acquisition support	- Explicit - Systematic - Timely - Value-added - Efficient - Amount & quality of support
Infrastructure development	- Number of federal and contractor HF support personnel - Experience of Support Personnel - Organization, management, and coordination of support personnel
Policy development	- Comprehensive - Effective
Process implementation	- Comprehensive - Effective
Professional Development and Training	- Comprehensive - Effective

Results/Recent Accomplishment: Within the human factors engineering program, major accomplishments were achieved in the following areas:
- Initiated Human Factors in Safety Management System
- Supported MA/IRT/IAT/ISR activities
- Developed an FY04 Human Capital Management Plan for Human Factors
- Created Guidelines for Integrating Human Factors in the Mission and Service Area Analysis
- Updated and published hardcopy Human Factors Acquisition Job Aid
- Conducted professional development and technical training for human factors community
- Reviewed and revised modules of web-based Human Factors Awareness Training/Tool
- Supported the development of an ATO staffing guide for acquisition product development activities

For the human factors infrastructure, policies and processes have been established to institutionalize and document the conduct of human factors endeavors, and training activities have been established to promote the awareness and understanding of human factors engineering concepts. Training of the general acquisition population continued to be emphasized principally through two means: (1) general awareness training, and, (2) technical training. Efforts to reach the broader population were improved with the upgrade of the final four (of 10) modules of a web-based Human Factors Awareness Course/Tool.

One of the most critical sub-elements of these strategies is to ensure that the appropriate level of human factors expertise is available. A staffing plan was drafted to manage and document this important objective. However, during the period of transition to the ATO, the availability of

human factors professionals to support system acquisitions has declined in supporting acquisition engineering functions. Hiring freeze policies and tight money have limited the availability of FAA or contract human factors expertise. This scenario of limited human factors resources presents at least two problems: (1) if human factors expertise is not readily available to advise about the human-system performance risks, risks will materialize too late to resolve them easily; and (2) the limited infrastructure does not allow for the coordination and exchange among other human factors expertise (such as the human factors research program) that would capitalize on human factors opportunities and lead to efficient use of FAA resources. Overall the efforts in integrating human factor engineering in FAA system acquisitions have continued. Many of these longer-term improvements require several years of development and a revised strategy for the new ATO organization.

Primary Investigator: Glen Hewitt, ATOP-R&D, Washington, DC

Producing Results – Aerospace Medical Research

Dr. Jim Whinnery manages a Aeromedical Research Program that addresses improved health, safety and survivability of aircraft passengers and aircrews. There are two major programs: toxicology and accident research, which evaluates medical findings gleaned from aircraft accidents to improve the safe operation of aircraft, and protection and survival research, which develops injury reducing materials and structures, and also evaluates survival equipment and procedures to protect aircraft occupants. The Aerospace Medical Research Program is focused on the following:

- Identifying human failure modes (physiological, psychological, clinical) in uneventful flight and during accidents and incidents. Here, researchers make formal recommendations for counteracting measures.
- Developing bioaeronautical guidelines, standards and models for aircraft cabin equipment, procedures and environments as a basis for regulatory action to enhance appropriate human performance.
- Reviewing pilot medical and flight histories and information from accidents and incident reports to develop new medical criteria, standards, and assessment/certification procedures to ensure fill performance capability.
- Preparing assessments of flight attendant and passenger behavior and disease issues to propose guidelines for actions that improve the health and safety of cabin occupants.

Aerospace Medical

Radiobiology Research - Annual Effective Dose of Ionizing Radiation from Natural Sources: Airline Pilots Compared with Non-Flying Residents of the United States

FAA Sponsor Organization: AAM-1

Purpose and Rationale: In evaluating health aspects of the ionizing radiation exposure of airline aircrews, risk estimates are normally based on occupational exposure to galactic cosmic radiation. However, aircrews spend most of their time on the ground. In this preliminary report based on 6825 U.S. airline flights, researchers considered the risk of fatal cancer as a consequence of ionizing radiation exposure from all natural sources received annually by pilots, both on and off the job.

Methodology: Estimated doses of galactic cosmic radiation while airborne and on the ground were calculated with CARI-6 software. Other sources of radiation taken into account were terrestrial gamma radiation, exposure to radon decay products, and radionuclides in body tissues. Annual radiation doses received by pilots who work on flights with origin and destination in the U.S. (50 states) and between the U.S. and foreign cities are compared with the average dose to non-flying residents of the U.S. and with the dose to non-flying residents of Environmental Protection Agency (EPA) Region 8 (Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado — a region in the U.S. with high dose rates of natural ionizing radiation at ground level). When off the job, pilots are assumed to be on the ground.

Results: Concern about fatal cancer as a consequence of occupational exposure to ionizing radiation may be unjustified for a majority of pilots because: (a) for 79% of the flight profiles in this study, the estimated annual dose of ionizing radiation received by the pilots from all natural sources was less than the annual dose to residents of EPA Region 8; (b) the annual dose of ionizing radiation to EPA Region 8 residents is 84% higher than the average dose to residents of the U.S. as a whole, whereas the death rate from cancer in the six states in EPA Region 8 is 3% to 26% lower than the average death rate in the entire U.S. A concern about fatal cancer as a consequence of occupational exposure to ionizing radiation is perhaps more reasonable for pilots who fly between the U.S. and Europe. All who worked such flights received higher annual radiation doses than residents of EPA Region 8. If epidemiological studies clearly indicate that airline pilots as a group are at an increased risk of developing fatal cancer, perhaps other environmental factors in addition to galactic cosmic radiation are involved. Another possibility is that the method of calculating the effective dose received during air travel needs re-evaluation.

Recent Accomplishments: Dr. Wallace Friedberg was appointed as an organizing committee member for the 35th Committee on Space Research Scientific Assembly, Paris, France. A contribution by the Radiobiology Research Team was selected for oral presentation. The Radiobiology Research Team received a special research team award for its work in aiding the Federal Aviation Administration's effort to provide a safe environment for aviation passengers and crew.

Primary Investigators: Wallace Friedberg, Kyle Copeland, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Cabin Safety Research

FAA Sponsor Organization: AFS-210, ANM-115, AAM-1

Purpose and Rationale: CAMI researchers evaluate cabin safety problems and conduct research studies and tests relevant to survival in aircraft emergencies. The research team also evaluates the efficacy of survival equipment and procedures, based on requirements in emergency situations.

Methodology: Cabin safety (e.g., emergency evacuation) is evaluated through literature reviews, computerized mathematical modeling, and laboratory/field research studies employing human subjects. Unique research tools includes a water survival tank, narrow and wide-body aircraft simulators, aircraft escape systems, and laboratory facilities required to support processing and care of large numbers of research subjects. Expert on-site support is provided to industry research and testing related to certification of transport airplanes, emergency equipment and procedures.

Results/Recent Accomplishments: Evacuation Into Water: Certification for transport airplanes requires that airframe manufacturers demonstrate that all passengers can be evacuated onto land within 90 seconds. Certification for ditching has generally been demonstrated via flotation-time analysis for each new airplane type. Differences in the proposed design and operation of new very large transport airplanes, e.g., the Airbus A-380, may create significant deviations from the historically assumed passenger flow rates into water. At the request of FAA's Transport Airplane Directorate, the CAMI Cabin Safety Research Team conducted a series of tests to evaluate evacuation flow rates into water from simulated Type A (42" wide) and Type 1 (24" wide) exits. The tests evaluated exit heights of 9", 2', 4' and 6' above water level with the subjects using flotation seat cushions, life preservers inflated prior to water entry, and life preservers inflated after water entry. Evacuation flow rates decreased as exit heights above the water increased, and evacuation rates for subjects using flotation seat cushions was slower than evacuations with subjects wearing life vests. The results were presented at the Scientific Meeting of the Aerospace Medical Association.

Computerized Evacuation Modeling: The evacuation capability of transport airplanes is typically shown by a full-scale evacuation demonstration or by a combination of partial demonstration and analysis based on prior full-scale demonstration data having similarity. Computer models have potential for more reliable and cost-effective assessments. Computer modeling of various types has been applied to the evacuation problem. The Cabin Safety Research Team has funded a grant to Rutgers University to assess the contribution of airplane cabin interior layout on evacuation.

Passenger Safety Awareness Research: Questionnaire data from subjects participating in a study of emergency egress through cabin emergency exits has been obtained to support a replication of a 1979 FAA study of passenger safety awareness. Analysis of pre- and post-September 11, 2001 data have revealed differences in the degree to which airline passengers attend to safety information in commercial airplanes, as well as the impetus for differences in paying attention. All passengers need alternate safety information presentation methods (i.e., an improved safety education curriculum). The results were presented at the Scientific Meeting of the Aerospace Medical Association; follow-on results will be presented at the International Aircraft Fire and Cabin Safety Research Conference.

Primary Investigator: Garnet A. 'Mac' McLean, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Forensic Toxicology Research - Analysis of Cocaine and 11 of its Metabolites

FAA Sponsor Organization: AAI-220, AAM-1

Purpose and Rationale: Specimens from fatal aviation accident victims are submitted to the FAA's Civil Aerospace Medical Institute (CAMI) for toxicological analysis. During the evaluations, drugs of abuse, including cocaine, are searched for in all cases. Cocaine (COC) is one of the most widely abused illicit drugs in America. Its abuse transcends all social, racial and economic boundaries. Following the introduction of a new form of cocaine in the mid 1980s called "crack," cocaine use has been on the rise. Because of its intense "high", crack smoking has become very popular. Despite its popularity, crack smoking is a particularly dangerous form of COC use. Additionally, COC and ethanol are frequently used together, resulting in the formation of a biologically active molecule that is nearly as psychoactive as COC; however it produces a longer lasting and more toxic effect. Such uses of cocaine can be predicted to have an even more profound altering effect on aviation performance. Demonstrating the presence or absence of COC and COC-related molecules in postmortem fluids and/or tissues may help determine the cause of impairment and/or death in pilots. It can also have serious legal consequences. CAMI researchers have developed a simple method for simultaneous determination of COC and COC metabolites (benzoylecgonine, norbenzoylecgonine, ecgonine methyl ester, ecgonine, and norcocaine), as well as anhydroecgonine methyl ester (a unique byproduct of COC smoking), cocaethylene (a molecule formed by the concurrent use of COC and ethanol) and their related metabolites, anhydroecgonine, norcocaethylene, and ecgonine ethyl ester.

Methodology: In this study, researchers incorporated a Zymark© RapidTrace™ automated solid-phase extraction system, gas chromatography/mass spectrometry, and PFP/PFPA derivatives. This procedure resulted in a rapid and sensitive method for the simultaneous quantification of COC and 11 of its metabolites.

Results: The extraction employed provided recoveries from 26% - 84%, with the exception of anhydroecgonine and ecgonine, which were recovered from 1% - 4%. The lower limits of detection ranged from 0.78 - 12.5 ng/mL, with the linear dynamic range for most being 0.78 3200 ng/mL. The methodology was applied to five aviation fatality cases. It has proven to be simple, robust and accurate for the simultaneous determination of COC and 11 COC metabolites in postmortem fluids and tissues.

Recent Accomplishments: Until recently, toxicologists had difficulty in determining the route of administration of cocaine and identifying all of the pertinent cocaine related compounds in a simple and timely manner. Forensic Toxicology Team researchers have developed a method to more accurately determine the many cocaine-related compounds. This will be an important aid in the investigation of aviation accidents. The route of administration of cocaine and the concurrent use of alcohol with cocaine can now be accurately determined. The Forensic Toxicology Research Team also took a leading role in the completion of a 2004 milestone entitled "Gas Chromatographic/Mass Spectrometric Confirmation of Beta-Blockers" as is discussed in the differentiation of beta-blockers section of this annual report.

Primary Investigators: Russell Lewis and Robert Johnson, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Biochemistry Research - Differentiation of Beta-Blockers in Biological Matrices

FAA Sponsor Organization: AAM-1, AAI-220

Purpose and Rationale: Pilots able to successfully control hypertension with diet, weight control and/or medications may be medically certified to fly civilian aircraft. Approximately 8% of active pilots are designated as "hypertensive with medication" by the FAA. One type of acceptable antihypertensive medication is the beta-blocker. Atenolol, metoprolol, and propranolol are included in this group. Not surprisingly, these medications have close chemical and structural similarities. The Civil Aerospace Medical Institute (CAMI) evaluates postmortem biological samples collected from pilots involved in fatal civil aviation accidents. Over the 10-year period, 1993-2002, CAMI identified 50 pilot fatalities in which beta-blockers were detected in postmortem samples. Atenolol was found in 24 pilots, metoprolol in 19 pilots, and propranolol in seven pilots. This frequent finding is consistent with these drugs being on the list of the most-prescribed drugs in the United States. Initial analysis in some of the fatality cases suggested the presence of both atenolol and metoprolol. However, there was no medical history in these cases supporting the simultaneous use of both of these drugs. It would also be unusual for patients to be prescribed or take more than one beta-blocker simultaneously. Therefore, further examination of the cases wherein atenolol and metoprolol were apparently present was undertaken to ensure the most accurate analytical procedures are employed in the forensic toxicology laboratory.

Methodology: Atenolol, metoprolol, and/or propranolol, along with their possible metabolite(s), were extracted from the selected case specimens, derivatized with pentafluoropropionic anhydride (PFPA), and analyzed by gas chromatography/mass spectrometry (GC/MS).

Results: The MS spectra of the PFPA derivatives of these antihypertensives and a metoprolol metabolite are nearly identical. All of the PFPA derivatives had baseline GC separation, with the exception of a metoprolol metabolite product, which was co-eluted with atenolol. There were four primary mass fragments (408, 366, 202, and 176 *m/z*) found with all of the PFPA-beta-blockers and with the interfering metabolite product. Therefore, this metabolite product could be misidentified as atenolol. However, atenolol has three unique fragments (244, 172, and 132 *m/z*), metoprolol has two unique fragments (559 and 107 *m/z*), propranolol has four unique fragments (551, 183, 144, and 127 *m/z*), and the metoprolol metabolite product has two unique fragments (557 and 149 *m/z*). These distinctive fragments were further validated by (1) using a computer program that predicts logical mass fragmentation, and (2) performing GC/MS of deuterated PFPA-atenolol and PFPA-propranolol and of the PFPA-alpha-hydroxy metabolite of metoprolol. By using the unique mass fragments, none of the re-examined pilot fatality cases were found to contain more than one beta-blocker. Several unique mass fragments reported in this study can be used for the positive identification of the three commonly used and chemically/structurally similar beta-blockers and a co-eluting interfering metabolite product of metoprolol.

Recent Accomplishments: These unique mass ions can now be used for differentiating and simultaneously analyzing beta-blockers in biological samples. It is now possible to definitively identify each beta-blocker without the uncertainty previously associated with atenolol and metoprolol interference.

Primary Investigator: Arvind Chaturvedi, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Functional Genomics Research

FAA Sponsor Organization: AAM-1, AAI-220

Purpose and Rationale: The Functional Genomics Research Team is equipped to investigate bioaeronautical factors related to aviation safety from a gene expression perspective. Experiments are designed to look at changes in gene expression in response to the physiological challenges associated with aerospace flight. Our long-term objective is to define and validate biomarkers that are affected by aviation stressors and to utilize these markers in the enhancement of aerospace safety, security and health.

Methodology: The research team is developing methods to determine gene expression by microarray analysis. We have the capability to examine up to 40,000 human genes in a single experiment. Analytical equipment is available to take advantage of experimental designs in single or dual color strategies. Array scans are initially analyzed by ArrayVision to generate fluorescence intensity data that is exported to the SPlus based ArrayAnalyzer statistical analysis software. In addition, a Minimum Information about a Microarray Experiment (MIAME) standard compliant Oracle database is available for data storage and public access through the Bioaeronautical Sciences Research Laboratory.

Results: An Office of Aerospace Medicine report was published (Vu, et.al., January 2004, "Isolation of RNA from Peripheral Blood Cells: A Validation Study for Molecular Diagnostics by Microarray and Kinetic RT-PCR Assays – Application in Aerospace Medicine") detailing the efforts of the laboratory to validate an RNA isolation method that allows RNA to be stabilized in shipment at 4°C.

Recent Accomplishment: The raw data has been gathered from a study investigating the effects of alcohol on gene expression. Data was gathered from six subjects at five blood alcohol levels over time. Data analysis is underway and preliminary analysis indicates that as many as 200 genes may be differentially regulated at different times in response to alcohol use. Two additional collaborations have been initiated, one to investigate the effects of fatigue on gene expression, and the second to assist in the validation of observed gene expression changes in response to cosmic radiation by quantitative PCR. (Note: see images, next page)

Primary investigators: Dennis Burian, Stephen J. H. Véronneau, Dennis V. Canfield, James E Whinnery, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Vision Research

FAA Sponsor Organization: AFS-300

Purpose and Rationale: The Vision Research Team (VRT) promotes aviation safety by investigating topics related to vision and their effect on aviation personnel and operations. VRT activities include: supporting the medical certification process by assessing the benefits and liabilities of ophthalmic devices and surgical procedures used by aviation personnel; evaluating the effects of aging and chronic disease on visual performance; identifying suitable vision screening procedures and techniques for the assessment of visual performance; and reviewing vision standards and their effectiveness for aviation personnel.

Methodology: Research activities are performed by VRT members with a high level of expertise and experience involving a broad range of vision-related technologies, physiology, and science. Researchers investigate various aspects of vision and aviation safety by reviewing scientific literature, analyzing medical and accident/incident databases, and conducting on/off-site data acquisition and analysis. When appropriate, human subject testing may be conducted in the vision laboratory that includes state-of-the-art ophthalmic instruments and a fully equipped refracting lane.

Results: The VRT collaborates with national agencies and international organizations to assist in drafting guidance materials and developing standards for aviation personnel related to vision. Research activities for 2004 included assisting the Society of Automotive Engineers' G-10T (Laser Safety Hazards Subcommittee) with development of the Aerospace Recommended Practice "Control Measures for Laser Safety in the Navigable Airspace," and the 6th Standards Subcommittee in revising the American National Standards Institutes "Outdoor Laser Safety Standard". VRT members assisted the International Civil Aviation Organization's Laser Emitters & Flight Safety Study Group with development of the "Manual on Laser Emitters and Flight Safety" which contracting states will use to guide establishment of outdoor laser safety programs that ensures aviation safety. Other completed research includes published reports on demographics and vision restrictions in civilian pilots and the effects of laser illumination on pilots in final approach and landing procedures. Several educational posters were developed and presentations were provided to aviation and eye care professional groups on the proper use of ophthalmic devices and refractive procedures for aviation personnel. On going projects include evaluation of vision standards for nondestructive inspection and testing personnel, assisting in development of a test plan to compare standard runway approach light systems with a strobe light approach light system, and drafting educational brochures on selection and use of sunglasses for aviation activities and laser refractive surgery for airman.

Recent Accomplishment: VRT investigators conducted facility and personnel surveys as well as detailed visual-task analysis at aircraft maintenance facilities. In addition, vision screening of 150 aircraft maintenance workers was performed at two facilities. Consolidation and analysis of the data collected during the study is ongoing.

Primary Investigator: Van Nakagawara, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Medical Research

FAA Sponsor Organization: AAM-1

Purpose and Rationale. The Medical Research Team conducts medical and laboratory studies of aircraft accident victims, including invited on-site participation, to analyze medical, engineering, and human factors findings gained from such cases. Researchers conduct appropriate research into the relationships of findings to the safe operation of aircraft. They also develop methods to improve their understanding of these factors in aircraft accidents, and evaluate performance decrements resulting from disease/physiological processes to determine their effects on aerospace safety. An additional responsibility is research to develop aeromedical and life support equipment guidelines for commercial space travel.

Methodology: Pilot Incapacitation Research: Relationship to Age. Although it is not known when the first accident due to pilot in-flight medical incapacitation occurred, a recent survey showed that almost one-third of all pilots who responded had experienced an incapacitation requiring another crewmember to take over their duties, with safety of flight significantly threatened in 3% of cases. The importance of in-flight medical incapacitation and impairment can be better understood when it is realized that each in-flight medical incapacitation or impairment could potentially lead to an aircraft accident. The Medical Research Team studied in-flight medical incapacitations and impairments in U.S. airline pilots from 1993 through 1998. In-flight medical incapacitation was defined as a condition in which a flight crewmember was unable to perform any flight duties. Impairment was defined as a condition in which a crewmember could perform limited flight duties, even though performance may have been degraded.

Results/Recent Accomplishment: Research found 39 incapacitations and 11 impairments aboard 47 aircraft during the six-year period. All pilots were males. The average age for incapacitations was 47.0 years (range 25 to 59 years). The average age for impairments was 43.3 years (range 27 to 57 years). The in-flight medical event rate was 0.058 per 100,000 flight hours. The probability that an in-flight medical event would result in an aircraft accident was 0.04. Incapacitations significantly increased with age with more serious categories in the older age groups. The most frequent categories of incapacitation were loss of consciousness and cardiac, neurological, and gastrointestinal events. Safety of flight was seriously impacted in seven of the 47 flights and resulted in two non-fatal accidents.

Primary Investigator: Charles DeJohn, FAA Civil Aerospace Medical Research Institute, Oklahoma City, OK

Biodynamics Research

FAA Sponsor Organization: ANM-100

Purpose and Rationale: The Civil Aerospace Medical Institute's Biodynamic Research Team evaluates the injury potential of new aircraft seats, restraint materials, and structures by utilizing advanced computational and dynamic impact test techniques under simulated crash environments. Research products are provided directly to support FAA aircraft certification and rule-making organizations.

Methodology: The team uses the CAMI impact test sled, static test procedures, mathematical dynamic models, instrumented anthropometric test dummies, high speed digital video recording and other research tools to evaluate aircraft occupant restraint systems and seats. Results are often of a sensitive nature and are provided directly to FAA sponsoring organizations. Open literature publication is accomplished when the results are of widespread value.

Results: The research team completed an assessment of a head-impact-criteria component tester (HCT). Current rules and guidelines for the certification of aircraft passenger seats can require full scale dynamic sled track testing for relative minor design or materials changes. In response to a congressional mandate addressing this issue, the FAA Air Transport Directorate (ANM-100) and the Aircraft Engineering Division of Aircraft Certification Service (AIR-100) initiated a program to develop improved/simplified methods to conduct aircraft seat certification testing. The National Institute for Aviation Research, Wichita State University received funding to develop the HCT in an effort to simulate the motion and forces that result from occupant head impact on an aircraft structure or seat. The Biodynamics Research Team conducted 11 sled tests and six component tests to complete evaluation of the HCT. The team also conducted a cooperative test program with the US Army Aeromedical Research Laboratory to evaluate restraint systems for air and land vehicles. Rigid seat sled tests were conducted evaluate various aircraft and ground vehicle restraint systems (including airbags) in horizontal, vertical and side-facing orientations. Data provided will be published by the Army and used to improve existing designs and assist designers of new aircraft and ground vehicle systems. The test information adds to the FAA knowledge base relative to the impact protection provided by these systems and will support future certification efforts.

Recent Accomplishments: The research team completed 23 rigid seat sled tests in a vertical orientation to determine the occupant's response when seated on various aircraft seat cushions. Data was provided to Wichita State University for use in development of a component test method for seat cushions. The team also completed five sled tests to evaluate the Robinson R-22 and R-44 helicopter seating systems. Since these seats are integrated into the fuselage structure, the entire fuselage forward of the firewall was mounted on the sled for each test. The data from these tests will be used to improve designs for the new R-66 helicopter now under development. A Dynamic Impact Procedures Training Class for Crash Dynamics was conducted to provide a hands-on demonstration of testing technologies to the students. Researchers also evaluated existing CAMI and industry provided restraint system test data to provide technical support for restraint system replacement policy development.

Primary Investigator: Rick DeWeese, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Bioinformatics Research

FAA Sponsor Organization: AAM-1

Purpose and Rationale: An aviation warehouse was developed to permit studying the complete population of civil pilots. This study of atrial fibrillation among civilian pilots is being used to develop query methodology to help characterize the aeromedical aspects of atrial fibrillation and medical certification decision-making. As a part of this project, a method is being developed to track the contribution of time by individual pilots, which will improve denominator estimates of exposure. Comparisons between groups of pilots with various medical conditions will be possible by comparing how long pilots remain in the National Airspace System before, during, and after the development of medical conditions. Special issuance groups will be followed in this manner. Relationships to outcomes such as accidents, incidents and deviations will be made. Expertise with large datasets and modern analysis and modeling techniques is used with the gene expression research microarray experiments being conducted at the Civil Aerospace Medical Institute (CAMI).

Methodology: Fact-based aeromedical decision-making requires epidemiological methods of surveillance, data mining and hypothesis-driven testing. Oracle relational databases and data warehousing are developed and utilized to marshal aviation medicine certification data with FAA and National Transportation Safety Board (NTSB) mishap investigation data. S-Plus, Dataminer 3 and other analysis software are used to study complex relationships and attempt to assess the aviation safety data with respect to medical certification information. Image processing and ArrayAnalyzer are used to analyze the data from oligonucleotide microarrays to determine differential human gene expression in the blood of subjects performing on a driving simulator while drinking alcohol.

Results: Medically certified pilots with atrial fibrillation have demonstrated a similar safety record as that of the overall aviation safety record. This supports current medical certification decision-making logic. Atrial fibrillation is the most common clinical dysrhythmia seen in clinical practice and increases with age. It is also associated with significant morbidity and mortality, including events associated with sudden incapacitation (cardiovascular and cerebrovascular events). Current clinical treatment modalities for atrial fibrillation are currently undergoing considerable evaluation and modification. Analysis and definition of the characteristics of pilots in civilian aviation are important to maintain optimum certification decision-making. Toxicological analysis performed at CAMI is used frequently by the NTSB in determining probable cause and assigning drug findings as factors or causes in aviation and surface transportation mishap investigations.

Recent Accomplishment: Creation of a research resource, the AAMD-DSS warehouse, continues and remains unique among civil aviation authorities in the world.

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FAA Sponsor Organization: ANM-150S, AAM-1

Purpose and Rationale: FAA's environmental physiology researchers study environmental factors, including biological/chemical threat environments that detrimentally influence human functioning, physiology and safety in aerospace environments. The team evaluates emergency situations to determine adequacy of aircrew protective systems for altitude and toxic environments. The team is directly involved in the development of improved test methodology and procedures to optimize performance in face of environmental hazards.

Methodology: Environmental Physiology Research (EPR) conducts extensive literature reviews and coordinates with standards groups to maintain cognizance of the state-of-the-art in aircrew protective systems. The team uses the full range of physiological test devices, the FAA's research altitude chamber, the flight deck environment simulator, and the Boeing 747 Aircraft Environment Research Facility to conduct evaluations of aircraft environment and aircrew protection systems.

Results: Development of time-accurate models of cabin airflow has continued in collaboration with the University of Tennessee Computational Fluid Dynamics (CFD) Laboratory. This work has the potential to best address cabin air quality issues aboard aircraft that range from optimizing environmental control system (ECS) parameters under normal operations to the most effective management of a chemical or biological threats intentionally introduced into the cabin during flight. The ramifications of this approach have been recognized throughout the aviation industry and resulted in two cooperative research and development agreements (CRDA) this year. One CRDA involved investigating methodology to decontaminate an aircraft interior, or potentially,

prophylactically clean the interior of active biological pathogens. Test runs were also made with the methodology to further validate the CFD simulations and provide insights into species transport within cabin airflows. The second CRDA supported incremental development of the cabin ECS systems in that the work is providing characterization of the gasper system that is commonly available on transport aircraft. The results will provide quantitative insight into how the gasper system is influencing the overall cabin flow field. The data is important in understanding how the different components of the ECS interact and thereby how they can be optimized. The EPR area completed an evaluation of protective breathing equipment in support of the Air Force Office of Special Investigation. This study defined the reliability of personal protective equipment purchased by the Air Force, Secret Service, and FBI for protection against contaminated environments.

Recent Accomplishment: Mass flow issues related to species transport from the CRDA experiments were successfully resolved. The reports characterizing the validation of the species transport CFD simulation and decontamination results were drafted. Collection of the dimensional data has been completed and the results are being analyzed. Results of equipment testing conducted for the Air Force have been prepared for presentation and publication.

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